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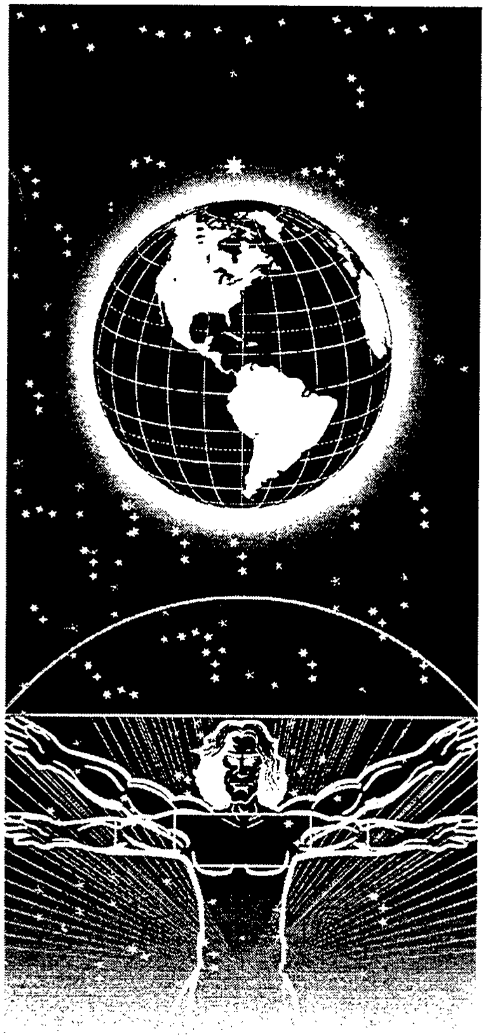

UNITED STATES AIR FORCE RESEARCH LABORATORY

TACTICAL TEAM RESOURCE MANAGEMENT EFFECTS ON COMBAT MISSION TRAINING PERFORMANCE

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

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This report describes Tactical Team Resource Management (T2RM) behaviors exhibited by Special Operations Forces MC-130P aircrews (aircraft commander, copilot, left navigator, right navigator, flight engineer, loadmaster, and communication specialist) as they planned and executed a simulated combat mission during annual simulator refresher training Five crew process elements (situational awareness; function allocation; time management; tactics employment and communication) and several indices if mission performance were recorded for five specific mission phases (mission planning, low-level operations, airdrop, air refueling, and infiltration/exfiltration). Team process overall was highly related to mission performance ($r = .86$). All of the crew process elements except communication were also predictive of overall crew performance. The relative predictive value of the specific process elements varied across the five mission phases, but the predictive value of communication was consistently low. Several structural and crew demographic variables were also explored with crew size, focus, and squadron affiliation appearing to have large effects. We summarize our main findings within the context of past cockpit resource management (CRM) research and MC-13P operations. We conclude the report with several recommendations for the conduct of CRM training based on our findings and observations.

14. SUBJECT TERMS
Aircrews; Annual Refresher Training; ART; CMT; Combat mission; Combat Mission Training; Flight simulators; Mission Rehearsal; MR; Performance Resource management; SOF; SOFNET; Special Operations Forces; Teams; Training devices

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PREFACE

This research was performed for the Warfighter Training Research Division of the Air Force Research Laboratory's Human Effectiveness Directorate (AFRL/HEA) (formerly known as the Aircrew Training Research Division of Armstrong Laboratory, Human Resources Directorate (AL/HRA)), by Anacapa Sciences, Inc. and Hughes Training, Inc. (HTI) - Training Operations under Contract F41624-95-C-5011. The objective of this contract was to provide behavioral research support in the areas of combat mission training and mission rehearsal. Anacapa Science, Inc. serves as a subcontractor to HTI on this effort, providing scientific and technical support. The contract effort was conducted under Work Unit 1123-B2-06, Aircrew Training Research Support. The Laboratory Contractor Monitor was Mr Daniel H. Mudd; the Laboratory Technical Monitor was Dr Robert T. Nullmeyer. The inhouse effort was conducted under Work Unit 1123-B3-01, Special Operations Forces Aircrew Training and Mission Preparation Research, with Dr Nullmeyer as the workunit monitor.

We would like to acknowledge several individuals who contributed generously of their time and support to this research. We would first like to thank LTC Ed Reed (USAF, retired) who was the Commander of the 58th Training Support Squadron (58 TRSS) throughout much of the duration of this project. He provided us access to the people and the state-of-the-art technology associated with the 58 TRSS. We would also like to acknowledge Mr John H. Fuller, Jr., HTI's program manager for his guidance and encouragement throughout this effort. We would especially like to thank the HTI Annual Refresher Training Instructors at Kirtland Air Force Base NM and the Special Operations Forces (SOF) MC-130P participating aircrews, whose cooperation, input, and tolerance made this research possible.

Several other individuals deserve specific mention for their help in interpreting our data, understanding the SOF MC-130P mission, and providing support. These individuals are listed below in alphabetical order:

Mr Dave Fiegel
Mr John Flournoy
Maj Dan Hernandez
Mr Phil Nelson

TACTICAL TEAM RESOURCE MANAGEMENT EFFECTS ON COMBAT MISSION TRAINING PERFORMANCE

INTRODUCTION

This report describes the results of research that examined the relationship between team coordination and tactical performance during a simulated mission that was conducted as a natural phase of Special Operations Forces (SOF) combat mission training (CMT). The work was performed at the 58th Training Support Squadron (58 TRSS), Kirtland Air Force Base (KAFB), New Mexico, using their state-of-the-art simulation complex which is capable of supporting CMT and mission rehearsal (MR).

Overview

In Spiker, Tourville, Silverman, and Nullmeyer (1996), we presented a conceptual framework for the measurement and evaluation of Crew Resource Management (CRM)-based skills. This framework expanded the scope of traditional CRM analyses to encompass the actions of an entire combat team and established the methodological foundations for the present empirical study. We will accordingly refer to the companion report many times throughout this paper. As outlined in that report, our primary objectives are to: (a) identify CRM-based processes for which CMT technologies are, or can be, utilized by aircrews and other mission participants; (b) document evidence of training effectiveness using these processes and technologies; (c) identify the characteristics or key behaviors emitted by the most effective aircrews; and (d) recommend opportunities for improving CMT through more effective reinforcement of the key behaviors. The concepts discussed in that framework and examined in this report concern the performance of SOF MC-130P Combat Shadow aircrews during a simulated CMT session. However, we believe that the concepts, methodologies, and results of the present effort will be applicable to other weapon systems within the SOF arsenal as well as other USAF assets.

The report is presented in five major sections. The remainder of this first section describes how CRM training and research has evolved during the past few years, discusses the conceptual underpinnings of crew coordination and its role in CMT, defines our conception of tactical team resource management (T^2RM) and its relationship to CRM, presents a measurement model of T^2RM, and reviews some of the tri-service research relevant to this framework.

In the second section, we introduce the present research effort by discussing our research objectives, hypotheses, MC-130P tactical operations, and the role of CMT during Annual Refresher Training (ART) at the 58 TRSS. The third section describes the research methods, including the participants, design, data collection instruments, assessment procedures, observational techniques, and the resulting data structure.

The fourth section describes the empirical results from the present effort, focusing primarily on the statistical relationships between measures of crew coordination effectiveness on the one hand and observed mission performance on the other. A series of analyses is presented that hierarchically decomposes the overall process-performance relationship into its constituent

elements, in which subprocesses and mission phases are considered. Also in this section, we address the effect of mission preparation (MP) on mission performance, present a preliminary analysis of the key behaviors associated with the most effective aircrews, and assess the influence of several background variables (e.g., organic crew size) on mission effectiveness. The fifth section concludes by discussing the implications of the present results for conducting further tactical team resource management (T^2RM) research, applying the empirical data to other USAF research and development (R&D) areas of interest, and administering CMT within the 58 TRSS.

Evolution of CRM Training and Research

During the past 20 years, CRM has become a widely used component of aircrew training programs for both the civil and military communities (Gregorich & Wilhelm, 1993). In a landmark study of the effects of workload on aircrew performance, Ruffell Smith (1979) reported that the behaviors which most differentiate effective crews from weaker ones involve leadership, decision making, and resource management, thereby establishing the need for training "softer" as opposed to more technically-oriented skills. Although not fully accepted by crewmembers, researchers believed that training in these areas would yield large dividends in terms of increased flight safety, more evenly distributed crew workload, and more efficient communication.

In reviewing the evolution of CRM training and evaluation, three trends stand out. The first pertains to **operational relevance**. Early CRM training programs failed to define the required aircrew coordination behaviors in operational terms. Rather, CRM was viewed as a loose collection of psychology, leadership, organization, and management concepts (A. Diehl, personal interviews, November 1995). The behaviors and attitudes that were trained were often too "touchy feely" to support either development of concrete indices or to be accepted by aircrews as necessary for flying the aircraft (Helmreich, 1995). Typical CRM topical areas included communication processes, team building, and workload management (Gregorich & Wilhelm, 1993), where it is not immediately clear what the reinforceable or observable behaviors associated with these areas would be. It is also possible that such training might not be maximally effective in a more tactically oriented, CMT setting, as CRM's traditional focus on nontechnical areas would be overshadowed by tactical and combat skill requirements.

In response to these criticisms, both the airlines and military attempted to add more "technical meat" to CRM course content. Functional areas that have increasingly found their way into CRM courses cover such accident-related topics as situation awareness, command authority, resource utilization, and operating strategy. Efforts to augment the technical base of CRM course offerings are still underway, with more work clearly needed (Wilson, 1995).

A second trend concerns the **specificity** of CRM training, in which the early programs were quite generic, with all airlines and airframe types receiving similar training. Indeed, a "one size fits all" strategy characterized the initial efforts of both the airlines and the military. While the generic nature of this approach proved efficient for administering large-scale courses and creating widely applicable flightline checklists, its effectiveness has not withstood empirical scrutiny (Wilhelm, 1991).

Recently, some airlines have taken a more problem-oriented approach in which a given airline explores the particular CRM-related problems that plague its operations rather than taking a global, industry-wide perspective. Given its diverse missions and multiple major commands, the USAF has been somewhat slower to move toward weapon system-specific simulator training and the corresponding administration and assessment of CRM course materials (D. Wilson, personal communication, September 26, 1995).

A third trend is evident regarding the **target audience** for CRM training. CRM courses in the early 1980's attempted to improve the attitudes of aircraft commanders (ACs) in order to promote more communication and information-sharing in the cockpit. CRM training in the airlines was designed to impact selected captains by "fixing" those most likely to resist information from copilots (CPs) or other crewmembers in time-critical, high workload situations (Helmreich, 1995). Similarly within the USAF, CRM training was originally focused on individual ACs. Over time, coordination concepts have been expanded to include other crewmembers, where it may ultimately encompass the entire mission team, including intelligence (Intel), tactics, logistics, weather, airborne command and control (C&C), air traffic control (ATC), maintenance, and so forth (Andrews, Bell, & Nullmeyer, 1995).

Important CRM components include delineating: CRM principles tied to operationally relevant behaviors, the appropriate target audience, and context-specific effects. Incorporating these components into CRM training programs will, in turn, enable researchers and training specialists to reinforce specific CRM behaviors for particular crewmembers, increase crewmember and instructor motivation to learn and apply CRM principles, and ultimately, establish an environment for determining CRM training effectiveness.

Despite increasing recognition of the importance of CRM, there is little evidence for a direct relationship with mission performance. This is particularly true in the context of CMT. While there is a vast body of literature concerning aircrew coordination, only a small subset of that has addressed CMT (Silverman, 1994). Moreover, though it is commonly assumed that effective aircrew coordination, however defined, leads to improved mission performance, very few studies have demonstrated an empirical link using tactically realistic training scenarios. One objective of the present effort is to provide such evidence while avoiding some methodological pitfalls that have plagued previous research (Spiker, Tourville, Silverman, & Nullmeyer, 1996).

Combat Mission Training and Tactical Team Resource Management (T^2RM)

CMT for the MC-130P is an integration of multiple training events that combine to transform an aircrew into a mission-ready combat team. In terms of ART, CMT is a combination of CRM academics and simulator training, technical training (e.g., emergency procedures (EPs) and systems), and combat tactics (Wilson, 1995). The latter covers a range of events, such as threat recognition, expendables deployment, mission planning, air refueling (AR), low-level navigation, and covert insertion and extraction. It is this added emphasis on developing tactical skills that makes the study of military teams so different from its commercial counterpart, necessitating the development of customized measurement procedures and data collection instruments.

The traditional, crew-level conception of CRM will have limited applicability to the complex, turbulent CMT environment. This view was substantiated during pilot tests, observations, and interviews conducted with SOF subject-matter experts (SMEs) in the early stages of this project (Spiker et al., 1996). On the basis of these front-end analyses, we have adopted a "tactical team resource management" or T^2RM, model as a logical extension of the CRM approach discussed above. As the name suggests, T^2RM embraces three elements that distinguish it from CRM: (a) clear delineation of a combat mission team; (b) enhanced focus upon tactical skills; and (c) an emphasis on managing a multitude of diverse resources within a dynamic environment. Each element is briefly discussed below.

Tactical Skills

From previous studies of SOF missions (Spiker & Campbell, 1993; 1994; Spiker, 1995), we know the content of T^2RM must contain a heavy tactical component in which combat skills, rather than communication, attitudes, and interpersonal relationships, are emphasized. Successful conduct of a SOF operation places heavy demands on the tactical skills of all crewmembers, where information is uncertain, decisions are split-second, and timing is all-important. Aircraft must be operated at low altitude, under adverse weather, in the midst of relocatable threats, and with no margin for error (Spiker & Campbell, 1993). A comprehensive T^2RM approach must ensure that reliable measures are obtained in such tactical areas as navigation accuracy, threat avoidance, meeting control times, and accomplishing critical mission events. The specification of the requisite tactical skills will, accordingly, be highly mission- and weapon system-specific.

Combat Mission Team

A primary focus of the T^2RM approach is its emphasis on the behavioral processes of the entire combat "team," and as such, is intended to investigate those variables that both measure and predict team performance. As used here, a team is composed of those players whose information, actions, and decisions impact the aircrew's mission in some way (Andrews et al., 1995). Besides the aircrew itself, this includes such mission participants as Intelligence (Intel), planners, weapons and tactics, logistics, weather, airborne C&C, ATC, maintenance, as well as the ground "customers" (Rangers, SEALs, etc.) being supported by the Air Force Special Operations Command (AFSOC) aircrew. During CMT, actions of this extended team may be role-played by the instructors whose inputs are scripted to promote standardization of training. Such scripting is ideal from a research standpoint as it reduces unwanted variation across subject-crews. A comprehensive T^2RM model must ensure that the "data hooks" are in place so that key interactions between players within this extended "team" format are monitored and assessed.

Resource Management

Within traditional CRM, the "resources" that are to be managed primarily involve information, such that information-sharing (e.g., between AC and CP or pilots and other flight deck personnel) is encouraged. Indeed, early CRM work focused on creating a cockpit "climate" in which the pilot had access to as much information as possible concerning the safety, status,

performance, and positioning of the aircraft within the larger flight environment (Diehl, 1995). As applied to SOF operations, the T^2RM approach takes a somewhat broader view of the resources the tactical team must skillfully manage. In addition to information, the SOF team is required to manage its most precious resource--time--to ensure that all required mission events are performed within the demanding temporal constraints that are the hallmark of SOF missions. Another scarce resource that is managed within our T^2RM model involves the allocation of duties among a limited cadre of people. Because SOF teams must leave a minimal "footprint" when performing mission events, people and aircraft are kept to a minimum. Thus, effective T^2RM entails utilizing team members to their fullest. This allocation is not only important during the mission itself, it is also imperative during mission planning (Spiker, 1995). Consequently, an effective T^2RM model must accommodate requirements for collecting measurable data during the all-critical MP stage.

T^2RM Measurement Model

Conduct of T^2RM research within a CMT environment should be guided by a systematic, comprehensive measurement model. Such a model provides a common language to define the content of T^2RM functions, establish valid indices to measure T^2RM processes, and specify appropriate procedures for collecting T^2RM data. Figure 1 depicts the T^2RM measurement model (Spiker et al., 1996) used to guide the present research.

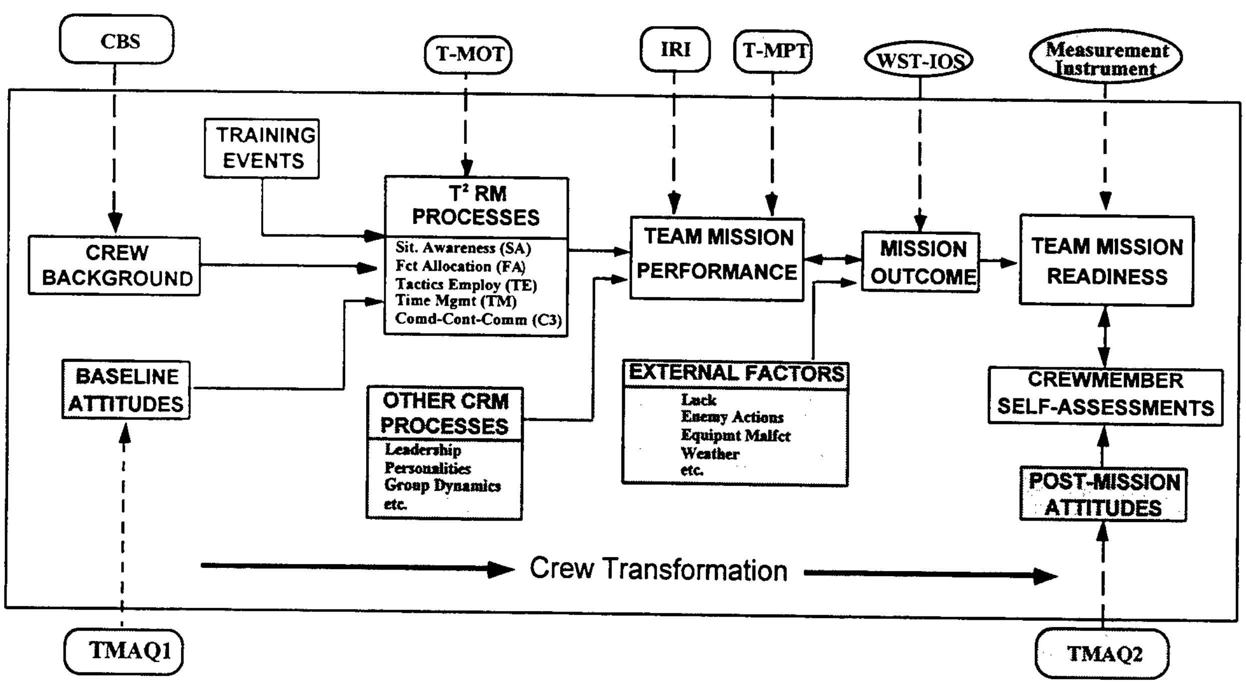

Figure 1. T^2RM Measurement Model (Spiker et al., 1996).

The concepts and linking arrows in the figure flow from left to right, reflecting an implicit timeline (arrival through outbrief) of ART activities. Three modules feed into T^2RM Processes. The first two, Crew Background and Baseline Attitudes, reflect the fact that aircrews vary in their background experience (e.g., squadron affiliation, hours flown as a crew) and attitudes toward CRM. To capture these factors, a Crewmember Background Survey (CBS oval) and a pre-Team Mission Attitudes Questionnaire (TMAQ1 oval) were administered. However, we have shaded the TMAQ1 (as well as the post-Team Mission Attitudes Questionnaire (or TMAQ2) oval) to indicate that we did not examine these factors within the present study.

While Training Events are represented as a single, undifferentiated component in the model, we recognize that the crew receives many salient training events during ART. These include CRM academics, relevant technical and combat tactics training, and the CMT mission scenario and scripted events that are presented before the crew flies in the simulator.

The five subprocesses depicted in the T^2RM Process module represents the content of our approach. They were selected for our research based on their relevance to the AFSOC mission environment, appropriateness to the high levels of experience and motivation of many SOF MC-130P aircrews, applicability to CMT, and amenability to measurement by outside observers (Spiker et al., 1996). Where possible, we attempted to identify subprocesses that make contact with the CRM dimensions identified by other researchers. The five T^2RM subprocesses and their formal definitions are shown in Table 1.

Table 1. Definition of Five T^2RM Subprocesses.

Subprocess	**Definition**
Function Allocation (FA)	The division of crew responsibilities so that workload is distributed among the crew, avoiding redundant tasking, task overload, and crewmember disinterest or noninvolvement, and where tasks are allocated in such a manner that crewmembers are able to share information and coordinate responsibilities.
Tactics Employment (TE)	All the analytic activities necessary to avoid or minimize threat detection or exposure, and to successfully coordinate complex mission events and multiple mission objectives.
Situation Awareness (SA)	Maintenance of an accurate mental picture of mission events and objectives as they unfold over time and space.
Command-Control-Communications (C3)	Those activities required to involve external parties in the mission and to maintain communications with these external team members; communication within the crew; and controlling the sequence of mission events according to the mission execution plan.
Time Management (TM)	The ability of the combat mission team to employ and manage limited time resources so that all tasks receive sufficient time to be performed correctly and critical tasks are not omitted.

These areas are depicted in the white T^2RM box in Figure 1 and were measured using our Team-Mission Observation Tool or T-MOT as indicated by the oval above. Since we know that these five areas do not encompass the entire domain of what would properly be considered T^2RM (or

even CRM), we represent Other CRM Processes in the gray-shaded box, feeding into the Team Mission Performance module. These processes may influence team mission performance, but were not measured in our research.

The output of the T^2RM Processes module feeds directly into the Team Mission Performance module. Team mission performance consists of those indices that directly result from the successful (or failed) execution of important T^2RM subprocesses (e.g., TE, FA). In our research, team mission performance is reflected in such indices as the quality of the pre-mission briefings, completeness of the navigation chart(s), and instructor-supplied ratings of how well the team as a whole and individual team members executed each phase of the mission. The ovals above the Team Mission Performance module refer to two tools (Instructor Rating Instrument or IRI and the Team-Mission Performance Tool or T-MPT) that we used to collect this information.

Mission outcome consists of indices that reflect whether the team accomplished its stated mission objectives. When performed in a weapon systems trainer (WST), these can often be recorded by computer. Outcomes include airdrop accuracy, performing airlands within prescribed time windows, on-ground time prior to airland, and minimizing (or avoiding) exposure to threats.

Mission outcome encompasses the criterion environment and is the ultimate yardstick of crew success or failure used by the operations and training communities. But from a team research standpoint, solely relying on outcome is risky as there are many external factors which may degrade outcome, yet have little bearing on combat team effectiveness. External Factors (e.g., luck) are illustrated in the gray box underneath the Mission Outcome module. Unfortunately, when assessing team coordination under operational conditions, researchers have little control over these external factors. As such, researchers inherit a great deal of noise and uncontrolled variability in their outcome measures, making it difficult to infer whether good or poor team coordination has occurred.

The Team Mission Performance and Mission Outcome modules are connected with a bi-directional arrow to indicate that some indices of team performance are based on data that would normally be used to measure mission outcome. Within our model, performance leads to interim outcomes that in turn affect subsequent team mission performance. For example, team coordination affects the quality of the mission execution plan, which in turn affects subsequent mission performance.

The Team Mission Readiness module reflects the end state of the crew at the conclusion of CMT. Following execution of the mission scenario in the WST and a formal debriefing by the instructors, the aircrew should be "transformed" into a team that is ready to perform similar operational missions. While such transformations are not observed directly, they can be inferred from behavior changes noted by trained instructors and by tracking how well the crew performs upon returning to its operational unit. We have placed an unspecified (shaded) Measurement Instrument oval above this module to reflect our belief that one can measure an aircrew's mission readiness, though such measurement was not part of our current research.

The last two modules are Post-Mission Attitudes and Crewmember Self-Assessments. They are represented in parallel to reflect the fact that this information was obtained from each participating crewmember using the TMAQ2. By comparing crewmembers' attitudes toward CRM after academic and simulator training with those obtained during the pre-ART baseline, researchers can determine the degree to which crewmember attitudes changed over the course of CMT. Yet it is important that one not mistake a relationship between training events and CRM attitude change for the more fundamental relationship between team coordination processes and team mission performance. It is this latter relationship that has the greatest implications for CMT and is the focus of our current research.

In sum, our T^2RM measurement model embodies a number of features that are critical for establishing direct links between team coordination processes and mission performance. These include: (a) providing multiple measures of team performance in addition to mission outcome; (b) assessing a series of tactically relevant coordination processes; (c) measuring team coordination processes and performance throughout the timeline of CMT events; and importantly, (d) emphasizing independent assessments of team coordination process and mission performance.

Relevant Tri-Service Research

A particularly useful application of the T^2RM model is to organize and interpret previous military CRM research. As is evident below, the knowledge base relevant to a T^2RM approach is limited. The purpose of this review is to give the reader an appreciation for the types of issues that have been studied and to convey the urgent need for empirical data that establishes the relationship between effective team coordination and mission performance.

Army

Since 1990, the Army has been conducting research to assess the effectiveness of its new Aircrew Coordination Training (ACT) program. ACT was developed in response to aviator critiques that "existing training packages for crew coordination lacked objective standards for measuring crew performance" (Leedom, 1990, p. 10). Defining crew coordination as "a set of principles, attitudes, procedures, and techniques which transforms individuals into an effective crew" (p. 10), the Army adopted a view of team transformation similar to that in our T^2RM model. ACT content was categorized into 13 subprocesses or Basic Qualities (BQs), such as decision techniques, communication acknowledgment, and information transfer. Each BQ is defined by a set of performance standards and evaluation dimensions. Instructor pilots (IPs) use the BQs to rate aircrew effectiveness during check rides much as they assess other technical tasks (Leedom, 1994).

An initial research study addressed the issue of attitude change—would aviators accept the new program? Surveys conducted at Fort Campbell showed that aviators and IPs did indeed exhibit positive changes in attitudes toward ACT over the course of training (Zeller, 1992). While encouraging, it was acknowledged future studies are required to substantiate whether ACT has a positive impact on either crew mission performance or mission outcome (Leedom, 1994).

One such study looked at performance of UH-60 Black Hawk aviators in a CMT simulated mission (Thornton, Kaempf, Zeller, & McAnulty, 1992). Team coordination was equated with communication, where each crew was assessed in terms of rate, pattern, content, and quality of interactions along the 13 BQs noted above (inquiry, command, declarative, etc.). Team performance (or mission effectiveness) was measured on three skills—navigation accuracy (ground track deviations), threat evasion (time exposed), and nonprecision instrument approaches (SME-rating).

Overall, there was evidence that communication was significantly related to some mission effectiveness indices. For example, crews who were more successful in evading threats had a pilot-flying (PF) who issued more acknowledgments than a PF counterpart in unsuccessful crews. Although rate of communication did not differ significantly among poorly performing crews (i.e., those who navigated inaccurately, were exposed to threats, and exhibited poor approach proficiency), there were trends suggesting that certain types of communication profiles were consistently related to positive outcomes.

The investigators concluded there is some evidence for a direct relationship between aircrew coordination and mission performance. However, there are two caveats that may limit overall applicability of their results. One, they observed rather low levels of technical proficiency on basic crew tasks—map interpretation, terrain identification, radio procedures—that should have been mastered prior to learning CRM skills. Two, their definition of coordination was, from our standpoint, fairly narrow since CRM processes other than communication were not included.

As an aside, Thornton et al. (1992) provided anecdotal evidence to support a positive relationship between quality of mission planning and mission outcome. Specifically, they noted that crews who performed better instrument approaches had spent more time studying the approach plates during planning, and thus needed to refer to them less often during the high workload landing phase. Such evidence encourages the CMT timeline depicted in Figure 1, in which measurements of team coordination encompass the entire mission, from mission planning through execution and debrief.

Navy/Joint Forces

The Navy has been pursuing an aggressive program of research to delineate the measurable aspects of team process and performance. Consistent with our T^2RM model, the Navy defines team coordination as the "essence of teamwork, the process, the moment-to-moment behaviors, by which interdependent team members achieve important goals" (Brannick, Prince, Prince, & Salas, 1995, p. 641). The purpose of the Brannick et al. study was to assess the validity of some a priori defined dimensions of coordination by having 18 judges independently rate a large number of two-person aircrews fly a low-fidelity, tabletop, T-44 flight trainer. Judges rated crews on six process dimensions—Assertiveness, Decision Making, Adaptability, SA, Leadership, and Communication—using a set of behaviorally anchored, 5-point rating scales. The Navy defined coordination more broadly than the Army, and even included processes (e.g., assertiveness, leadership) excluded from our model. To assess performance, an IP rated each crew on a 20-item checklist (completing flight checklist, making required altitude corrections, etc.). Two

nontactical mission scenarios (involving point-to-point flying) were flown by each crew. Half of the crews consisted of current Navy T-44 pilots; the other half were Navy IPs.

In support of their methodological objectives, Brannick et al. demonstrated consistency among the judges' process ratings across crews and scenarios. They also found a fairly strong relationship between the various team coordination process ratings and overall team performance, with correlations ranging from $r = .43$ to $r = .69$. Comparison of the process ratings between the two crew experience levels revealed a surprising lack of superiority by the IPs, with only Assertiveness, Decision Making, and Communication approaching significance. However, once statistical controls are imposed to correct for multiple tests of significance, none of the mean differences proved significant (Spiker et al., 1996). The lack of an experience effect may have been because the non-tactical mission scenarios were not sufficiently challenging to produce substantial performance variation across crews. Unfortunately, comparisons between IPs and trainees on the expert-supplied mission performance rating were not reported.

Recently, the Navy has been expanding their team process-performance methodology to distributed interactive simulation (DIS) environments. To that end, Dwyer, Fowlkes, Oser, and Salas (1996) designed a set of instruments to separately measure critical aspects of team process and team performance. In one test, they had a team of observer/controllers (OCs) observe DIS training for five days of Close Air Support (CAS) missions. The OCs completed the process and performance instruments in addition to role-playing the higher echelon positions needed to run the scenario. The investigators reported that their instruments were reliable, as OCs representing the different services exhibited similar response patterns. They also found that teams showed considerable improvements in both coordination process and performance from Days 1 to 5, suggesting a pronounced learning effect.

As seen through our measurement model, this study provides a rather complete picture of team performance within a combat mission environment. Indeed, one of the truly admirable features of this study is its examination of team coordination in a much larger combat team environment. Other praiseworthy aspects of this study include: on-line data collection with highly trained observers, collecting team process and performance data from separate sources, collecting data across multiple mission phases (planning, contact point, attack), and using a realistic tactical scenario. However, the authors fail to report any performance data to allow exploration of the fundamental team process-performance relationship.

In a follow-up study, Oser, Dwyer, and Fowlkes (1995) observed 13 and 18 service participants, respectively, in two CAS-DIS training exercises. As before, both case studies found marked improvement in team process and team performance over the five days of training. Unfortunately, process-performance correlations were not computed which would have shown which aspects of team coordination would impact different facets of mission performance. Nevertheless, these studies are some of the first to collect systematic team performance data in a DIS training environment, and should therefore help further the knowledge base concerning the training strategies that can be employed to enhance team performance.

Air Force

In an early study of crew coordination, Krumm and Farina (1962) investigated the impact of integrated simulator training on B-52 mission effectiveness. The investigators collected process data on the pattern and rate of communication between crewmembers during selected segments of the training mission. They also collected objective measures of navigation and bomb accuracy performance. They found that the method of training had a positive impact on coordination, as crews who trained together had better communication patterns than ones who did not. Quality of communication was also significantly related to navigation and bombing accuracy. For example, crews who navigated more accurately also volunteered more information.

More recently, Povenmire, Rockway, Bunecke, and Patton's (1989) study of B-52 aircrew coordination represents one of the strongest attempts yet to demonstrate a direct relationship between CRM processes and mission performance. This study employed a number of the methodological features we have discussed in our T^{2}RM measurement model, ones that we believe are particularly valuable for examining process-performance correlations in the context of CMT.

Povenmire et al. observed seven intact aircrews fly a complex, tactically realistic mission scenario in a high fidelity B-52 WST. The scenario entailed conducting a long-range bombing mission requiring the penetration of enemy threats, accurate dropping of bombs, and intricate navigation and maneuvers. SME CRM evaluators assessed aircrew coordination and mission performance, with separate raters used for each. Mission performance was evaluated on three factors: bombing accuracy, threat avoidance, and technical skill. The latter consisted of a number of subfactors, such as maintaining appropriate altitude, navigating accurately, and staying within designated control times. The researchers asked the evaluators to rank order the crews from best to worst, based on their subjective impressions of the three mission performance factors.

The main analysis was the correlation between overall aircrew coordination and crew mission performance ranking, where a strong positive relationship, $r = .84$, was obtained. Povenmire et al. then compared the experts' ratings of mission performance with the individual mission outcome factors. Part-whole correlations showed that experts primarily used bombing accuracy to judge overall mission performance, as evidenced by a correlation of $r = .81$. The researchers also computed a series of part-whole correlations on the coordination data to determine the skill dimensions that had the highest loadings. These included practicing inquiry and advocacy, avoiding distractions, distributing workload, and resolving conflicts.

Despite the simplicity of its design and data analysis strategy, the Povenmire et al. study stands as one of the clearest demonstrations of the relationship between crew coordination processes and mission performance. Indeed, the elegance of their design provides unusually clear insights regarding the crew coordination processes that best predict mission performance. As discussed in the next section, we used many of Povenmire et al.'s methodological features in our empirical study of T^{2}RM.

THE PRESENT RESEARCH EFFORT

This section provides background information pertinent to the present research. We begin by stating our research objectives and the hypotheses the study was designed to test. Next, we describe MC-130P operations and define the crewmembers who operate the aircraft. We close by describing how ART is conducted at the 58 TRSS, focusing on the training curriculum, CMT scenario, and the capabilities of the MC-130P WST.

Study Objectives

The objectives of the present research were established in accordance with three levels: immediate, near-term, and long-term. The immediate objective of the effort was to demonstrate a positive, robust relationship between team coordination and mission performance, thereby replicating the basic findings of Povenmire et al. (1989). With that relationship established, we then wanted to identify the characteristics (and key behaviors) of effective, mission-ready aircrews which may be incorporated into training program procedures and technologies. Another immediate goal was the development and validation of a robust set of data collection instruments that can be applied, with modifications, to other SOF weapon systems.

In the near term, we want to extend the present research and conduct a more controlled test in which one or more of the identified interventions are packaged as a set of training program variables whose impact will be assessed using a traditional control versus treatment group experimental design. Candidate training package enhancements might include:

- an enhanced CMT simulator mission scenario,
- a program of instructor reinforcem?ent of key CRM behaviors,
- CRM instruction tailored to a particular weapon system,
- selective crewmember cross-training of key tasks and skills (e.g., landmark identification),
- customized checklists of required planning activities,
- just-in-time training of perishable skills (e.g., electronic warfare (EW) tactics), or
- deliberate practice of key mission events and team tasks.

The long-term objective of the research program entails the eventual development of a portable, research-based instrument that identifies the team elements contributing to mission-ready aircrews. Ideally, such an instrument would give squadron commanders the capability to objectively assess the readiness of assigned crews to successfully perform a given mission. Termed the Team-Mission Readiness Assessment Tool (T-MRAT), this instrument could be used at the squadron level by mission commanders, IPs, and Standardization/Evaluation (Stan/Eval) personnel to assess the T^2RM standing of a proposed crew complement. The T-MRAT would quantify a crew's overall likelihood of mission success, identify weaknesses in a crew's composition, specify risks, and potentially suggest alternative crew configurations. The assessment tool would be primarily checklist in format, could be administered in a few minutes under austere conditions, and would be scorable on the spot. The role that the T-MRAT would play within our T^2RM measurement model is depicted in Figure 1 as the final "Measurement Instrument" oval.

Research Hypotheses

Five major hypotheses were derived from our T^2RM measurement model:

1. Team coordination processes should be strongly and positively related to mission performance. Crews who exhibit superior coordination behaviors should perform better during mission execution than those who do not. If found, this would extend the Povenmire et al. (1989) finding with B-52 Strategic Air Command crews to another weapon system and USAF major command. As described in Spiker et al. (1996), the process-performance relationship is the fundamental tenet of the proposed research, in which a significant finding "gives us permission" to probe the data further, to test the other hypotheses stated below.

2. The various T^2RM subprocesses should show differential relationships to performance across mission phases. Although we expect an overall process-performance relationship, we should not expect every T^2RM process to be significantly correlated with every phase of mission performance. We do not believe T^2RM to be a single entity. Rather, for performance in a given mission phase, only one or possibly two T^2RM subprocesses may be statistically significant predictors. For example, the FA subprocess should more likely have a significant impact on those phases of performance (e.g., low-level navigation) where allocation of crew duties can substantially reduce overall team workload. Such selectivity is a natural outcome considering that different phases of performance will require different types of crew involvement, interaction, and decision-making. While most, or all, the process-performance correlations across phases might trend positive, only 1-2 subprocesses should reach statistical significance.

3. The quality of MP should be strongly and positively related to mission performance. Simply stated, crews who do a more thorough job of MP should more successfully execute their mission than those who do not. While a positive relationship between planning and performance is at the heart of all military MP, there is surprisingly little empirical data to substantiate this all-important assumption. MP and its effects should be seen both as a process component—in which better team coordination during planning should lead to better mission performance—and as a performance variable, with better planning products (charts, briefings) associated with superior subsequent mission performance.

4. There should be measurable aspects of team structure that are statistically related to crew effectiveness. As defined by an amalgam of T^2RM coordination and mission performance rankings, the more "effective" crews should have some structural components in common that are not present in the less effective crews. Predictive structural variables might include such aspects as combined crewmember experience in the area of operations (AO), hours flown together as a crew, or level of experience for key crew positions (e.g., the two navigators). Alternatively, salient team composition variables might determine how crewmembers are organized (e.g., hierarchical vs informal) or how information is shared and disseminated.

5. There should be a positive relationship between the crew's perceptions of T^2RM effectiveness and mission performance. Crews should know how well they execute the various

T^2RM subprocesses and should be able to honestly report these upon completing the mission scenario. In general, one should expect that crews who perceive their coordination processes to have been successful will also report having performed better during the mission. Although such a finding lacks the independent observation of process and performance as in our other hypotheses, it would nonetheless provide supplemental validation of the relationship using an alternative data source.

MC-130P Tactical Operations

This section describes MC-130P Combat Shadow operations; the tactical missions executed and the crewmembers who fly them. Following this, a description of ART is provided, focusing on the present training curriculum, the CMT simulator scenario used, and the capabilities of the MC-130P WST. This discussion is intended to give a general overview of the concepts and terminology used in SOF operations.

Missions

In the broadest terms, the primary missions of the MC-130P Combat Shadow are: (a) AR support of SOF MH-53J Pave Low and MH-60G Pave Hawk helicopters, (b) aerial delivery of Special Forces (SF) and/or supplies, and (c) airland operations to austere landing zones. Other SOF missions include civil affair activities (programs to control or influence civilian activity) and/or psychological operations. The environment for such MC-130P operational missions is typically defined as a moderate threat theater. SOF aircrews typically attempt to accomplish their missions using night vision goggle (NVG) low-level procedures and precise timing techniques to meet mission objectives, and to avoid or minimize detection by hostile forces. Because the taskings of the MC-130P are so varied, it is difficult to construct a taxonomy that will apply in all circumstances. Thus, the abovementioned mission categories serve as inexact placeholders from which a combat mission simulator scenario can be constructed.

MC-130P Combat Shadow

The standard MC-130P aircrew consists of seven crewmembers. Five members perform their primary flight duties in the cockpit: the AC, CP, Left and Right Navigators (LN and RN), and FE. The Communication Systems Operator (CSO) and Loadmaster (LM) crew stations are located in the rear cabin compartment. For the purposes of this discussion, the LM is omitted. While the LM receives CRM classroom training with the rest of the crew on the first day of ART, he is trained at a separate site for the rest of the week and does not participate in the CMT scenario. This is primarily due to the lack of a simulation capability at the 58 TRSS to support the training of LM's technical and CRM skills. A general description of the other crewmembers' functions follows:

Aircraft Commander (AC). The AC is responsible for managing the overall mission process of the entire aircrew. Besides flying the aircraft, the AC monitors the progress of the crew's activities as they work to accomplish each mission objective. The actual amount of work

performed by the AC will vary with the individual, but ideally, the AC operates as the filter for all communications, and leads the decisions with respect to the mission's execution details.

Copilot (CP). The CP is responsible for supervising the mission process, as negotiated and established by the entire aircrew. The CP works to ensure that each mission detail is covered, and alternative courses of action (COAs) are considered. The CP participates with each crewmember as they work to accomplish each mission objective, and ideally, integrates those individual activities and accomplishments into a larger, synergistic mission effect.

Left Navigator and Right Navigator (LN/RN). The LN and RN are responsible for performing the many calculations required to support aircraft tactical navigation and dynamic timing and control activities throughout every stage of the mission. These duties include, for example, the development of tactical low-altitude flight routing to reach and recover from the AO, and to accomplish all major mission objectives in the threat environment.

Flight Engineer (FE). The FE is responsible for determining and managing the aircraft's performance characteristics (e.g., takeoff and landing distance, etc.). This information typically includes computing the aircraft weight and balance, field density and pressure altitude, based on environmental conditions. The FE is also responsible for management of the aircraft's engines, fuel systems, and electrical power systems, so that other crewmembers may concentrate on developing the mission scope or executing the mission details. In addition, the FE assists in establishing the crew's Escape and Evasion (E&E) plan in the event the aircraft becomes disabled.

Communication Systems Operator (CSO). The CSO is primarily responsible for constructing and executing the communications matrix in a Communications Execution Operating Instruction (CEOI) format. The CSO determines the radio type and frequencies to be used for each mission phase and/or objective. The CSO determines the C&C net to be employed with the other mission participants and ensures that the required coordination issues are established. Additionally, the CSO determines the extent to which the crew can conduct their tactics plan with "minimum emissions," so that they use the least amount of en route radio communications that might be intercepted by hostile ground parties. The CSO also typically reviews the communications capability of the in-country forces to determine the crew's Selected Area For Evasion (SAFE) and E&E plans, in the event the aircraft becomes disabled.

MC-130P Aircrew Training Devices

The primary aircrew training device used for MC-130P ART is a six-degree-of-freedom, high-fidelity WST based on the SOF Improvements (SOFI) version of the MC-130P Combat Shadow aircraft. This device includes a CompuScene V image generator system, a fully correlated Infrared Detection System (IDS), a digital radar landmass system, navigation systems, and out-the-window displays. Navigation systems include Doppler, inertial navigation system (INS), control display units, and a central computer system that integrates various flight systems.

The MC-130P Satellite Navigation System (SNS) is a part-task trainer used to train MC-130P navigators and CSOs. This device may operate either in an independent or integrated mode. When in independent mode, the device operates unconstrained by any other device and is used to train either the navigators or the CSO in crew position-specific tasks. The independent SNS might be used by the navigators, for example, to practice high-altitude, over,water, celestial navigation procedures, or by the CSO to practice secure communications procedures.

In the integrated mode, the SNS operates in conjunction with the MC-130P WST. Navigators may be trained in either the SNS or WST in this configuration, while the CSO remains in the SNS for orchestrated training with the students in the WST. This is the configuration that is typically used when the full MC-130P crew is tasked to conduct mission operations training. The pilots, navigators, and FE are located in the WST, while the CSO is located in the SNS. This is like the actual SOFI version of the MC-130P aircraft, where the CSO station is geographically separated from the flight deck in the rear cabin.

Annual Refresher Training (ART)

As discussed above, ART is a high-priority, annual training requirement for SOF MC-130P mission-qualified crewmembers. Content of this training is specified by appropriate regulations (i.e., AFSOCR 51-130: Aircrew Training), and the training matter is assumed to be relatively constant as aircraft systems and procedures do not change regularly. The ART curriculum at KAFB, however, has undergone major shifts with regard to both the manner and matter of training in recent years.

Only a few years ago, ART consisted mostly of academic classroom sessions covering aircraft-specific systems and EPs reviews. Following each half-day classroom session, students were then required to apply these lesson topics, using a partial-task training approach, in the WST. This modular training method worked well for many years, and those USAF units using this system were, for the most part, satisfied with the training provided. There was, however, a growing consensus in the relatively small SOF community that the expense of bringing crews to KAFB each year for a repeat of the same, predictable curriculum was becoming prohibitive. Students and operational squadrons justifiably recognized the capability of simulation as a training medium and wanted more for their training time.

The result has been a very noticeable shift in overall training philosophy from a systems training approach for individual crewmembers to a **combat mission training orientation for full mission teams**. Systems training was not deleted in this new training philosophy, rather, systems malfunctions now are required to be exercised in real time while immersed in the complex mission environment. Student crews performed their corrective actions to instructor-induced systems malfunctions and EPs while other live stressors also inflicted their toll on the mission team's actions.

Coincident with the shift in training philosophy, the KAFB aircrew training devices and host computers underwent significant system upgrades. The resultant increases in simulation fidelity afforded new and unique approaches to training that had not been previously possible. With the integration of EW systems, countermeasures, improved visual systems and correlated

sensors, among others, student crews could now perform real-world, operational missions in semi-immersion, simulation environments with a significantly increased training tempo.

The combination of improved simulation technologies, a strategy for implementing distance learning methods, and a customer thrust for a mission-specific and an operations training curriculum, naturally led to implementation of a CMT refresher philosophy. The following subsection describes the general sequence of curriculum events for the full week of ART.

ART Curriculum and Scheduling. The SOF MC-130P aircrew's ART curriculum is scheduled for five full-day sessions of training, which are equally divided into 10 half-day training periods (see Table 2). The first half-day of training provides an academic review of CRM principles and anecdotal discussions of recent, CRM-related experiences. Following this period, the student crew is separated into functional groups (pilots and FE, navigators, and CSO) to join their respective instructors and begin their week of aircraft- and mission-specific training.

Generally speaking, the remaining training periods are grouped into academic and simulator training sessions. Each day's instruction begins with an academic period, which focuses on a review of aircraft systems, EPs, and/or mission operations training using a variety of multimedia and multidelivery instructional methods. Following each academic period, students are required to apply the preceding academic period's topical matter in the simulator mission environment (e.g., engine fires during low-level operations). The intent is to provide a real-time stress environment for these crewmember groups so they may rehearse their individual and crew responsibilities and responses to instructor-induced malfunctions.

Table 2. Annual Refresher Training Schedule

1	**Academics**: CRM			**2**	**Academics**: Systems & Procedures		
	AC, CP, FE, LN, RN, CSO, LM				AC, CP, FE	LN, RN	CSO
3	**Academics**: Systems & Procedures			**4**	**Simulator**: Systems & Procedures		
	AC, CP, FE	LN, RN	CSO		WST: AC, CP, FE	SNS: LN, CSO	
5	**Academics**: Systems & Procedures			**6**	**Simulator**: Systems & Procedures		
	AC, CP, FE	LN, RN	CSO		WST: AC, CP, FE	SNS: RN, CSO	
7	**Academics**: Systems & Procedures			**8**	**Simulator**: Systems & Procedures		
	AC, CP, FE	LN, RN	CSO		WST: AC, CP, LN, RN, FE	SNS: CSO	
9	**Academics**: CMT – Preparation			**10**	**Simulator**: CMT - Execution		
	AC, CP, FE, LN, RN, CSO				WST: AC, CP, LN, RN, FE	SNS: CSO	

CMT Scenario. As illustrated above, several daily academic review and simulator practice and reinforcement sessions are provided in the ART curriculum. The last training day, however, entails a capstone project that is devoted to full-crew, mission-specific combat operations performance in a mission-relevant AO. The underlying objective of this real-time, mission operations training is to enhance overall CRM skill and performance. However, the stated intent is also to let the crew perform at a significantly higher intensity level to a mission tasking that is difficult, complex, and relevant to their real-world mission requirements.

This simulator mission scenario encompasses a complex series of multiple mission objectives that are scripted in real time to instructor- or crew-induced problems. Thus, students are tasked in this training to accomplish their planning and execution events that, in the simulation environment, are designed to push them to near overload conditions. The subsections that follow describe, in linear order, the unclassified portions of the CMT scenario that were used in our study, along with the corresponding student crewsí activities and general responsibilities at each step in the training day.

Mission Preparation (MP). The mission scenario begins with an extensive MP period. This period is designed to enable the crew to formulate a mission execution plan that is compatible with their capabilities and is responsive to dynamic mission environmental conditions. For example, a typical crew might use this period to prepare several mission products in response to the scripted mission fragmentary order (FRAG). These products might include, among others, a mission flight plan that contains navigation checkpoints and time control markers, an AR execution plan, and a Computed Air Release Point (CARP) prediction worksheet.

To begin the period, the MC-130P aircrew arrives at the mission overview, where they are provided a FRAG brief as if they have been pulled off alert status. While in alert crew rest, their scenario has been evolving and their particular general mission plan has been under development by a dedicated mission planning team. The simulated time is approximately four hours prior to launch. The crew's tasking is to "challenge" these planning efforts and to further refine the general mission plan provided to them. They are to coordinate all requests for information and relevant logistical details into an integrated mission execution plan that they can perform as the actual mission team.

Instructors are tasked to role play C&C elements of the mission tasking team, providing the crew with a general situation in-brief and periodic mission situation reports (SITREPs). Specifically, the initial briefing details that a simulated US Army platoon has reported casualties while conducting mine-clearing operations. Five additional members of the group have also suffered disabling injuries and require immediate medical evacuation (MEDEVAC) to a forward-deployed field hospital. Due to their proximity to unfriendly forces, the platoon's movement is restricted, and they are requesting immediate MEDEVAC. Two MH-53J Pave Low helicopters have been alerted to the situation and are tasked to transport the injured to the field hospital.

The MC-130P's primary mission tasking is to support the recovery of the injured personnel by providing AR tanker coverage for the exfil operation and MEDEVAC flight. To support this effort, the Shado flight is also tasked to insert, via a personnel CARP airdrop, several pararescue jumpers (PJs) at the evacuation Drop Zone (DZ). The intended purpose is to insert an SF team who will prepare evacuees for transport and prepare the landing site for the transload operation.

Secondarily, the MC-130P crew has also received a mission tasking to transport a flag officer and staff to the field hospital. This hospital is located on an airfield that is presently under joint control by indigenous army and rebel factions. The scenario calls for inserting these personnel under the semblance of a diplomatic negotiation team who will secure airfield landing

rights before the inbound, injured personnel arrive. Additionally, mobile threat systems have been recently reported in the surrounding countryside, and these should be considered hostile. This type of operation dictates the requirement to perform a covert approach and landing. After inserting the team, the MC-130P should immediately depart the airfield and continue its low-level operations and tactics to recover to its original departure location airfield.

The students are handed FRAG worksheets that detail these mission aspects, and provide certain required information for them to further plan their mission objectives. Specifically, they are given terminal, route, and objective area weather reports and detail charts; Operations and Communications Security details; Rules of Engagement; and Order of Battle threat details, among others. It is expected that the students will integrate these materials and other available information sources to develop an executable mission plan.

During MP, coordination with several key "players" may be required so that students can gain the necessary supporting information to properly prepare the logistics portion of the mission execution plan. To facilitate these coordination efforts, instructors role-play the functions of Intel, Tactics, ATC, maintenance, and weather. Other members of the combat mission team may exist whose tactical actions have a direct effect on the aircrew, such as SF on-board "customers" and other AFSOC aircraft that are participating in this mission script (e.g., the MH-53J helicopters that are to be refueled by the MC–130P). Besides the supporting and tactical players, those individuals and functions that provide a C&C role, such as the squadron/wing command leadership and the airborne command, control and communication (ABCCC) aircraft may be included as role players.

Table 3 presents a partial listing of the many roles and responsibilities of each crewmember during MP. The duties listed are not absolute. Depending on crewmember experience, expertise, or interest, these duties may be performed by other crewmembers or perhaps not at all. The table is intended to illustrate that each crewmember, and the crew as a whole, is heavily invested in activities that must be effectively performed and/or coordinated in order to prepare the final comprehensive mission plan.

The remainder of the MP period is spent conducting several pre-mission briefings that enable the crew to unite as a cohesive mission team. Once these briefings have been completed to the crew's desired level of detail, the crew should be focused on the mission objectives and the activities by which these objectives will be accomplished.

Mission Execution. Following the MP period (and lunch), the crewmembers enter, as appropriate, either the WST or SNS, and execute their mission plan with little or no direction or assistance provided by their instructors. The instructional premise is that this mission is to be executed *as if* the students were immersed in the actual aircraft (e.g., every checklist will be performed), in the "live" mission environment (e.g., all threats encountered are considered as potentially fatal if not acknowledged in a timely and appropriate manner). Responses to any self-induced, instructor-induced, or scripted stimulus condition are to be responded to in real-time, and if that response results in an undesirable situation or condition, the crew must live with their

decisions. Students are briefed that this mission is to be given the highest priority of execution, with overall mission success as the ultimate goal.

Table 3. Crewmember Roles and Responsibilities During Mission Preparation

Crewmember	Mission Preparation
Aircraft Commander (AC)	Reviews the mission tasking to provide an initial risk assessment. Accepts the crew's mission plan and prepares/coordinates the mission execution briefing. Prepares/coordinates requests for "outside" agencies to provide necessary logistics support.
Copilot (CP)	Reviews mission details to ensure that all COAs are considered and the mission's risk assessment is correct. Works with the RN to validate threat capabilities and establish a tactics execution plan. Checks the FE's Takeoff and Landing Data (TOLD) and other computations.
Left Navigator (LN)	Prepares the Flight Chart with all annotations necessary for low-level, NVG flight operations (e.g., route of flight, waypoint information, terrain obstructions, etc.). Organizes the mission data to facilitate programming of the aircraft's mission computers.
Right Navigator (RN)	Performs threat capabilities analyses and prepares the tactics execution plan. Computes the CARP worksheet and prepares the airdrop plan. Prepares the AR rendezvous, join-up, and contact plans; proposes alternative COAs in the event the AR is unsuccessful.
Flight Engineer (FE)	Computes the aircraft fuel management plan. Computes the aircraft weight and balance data, and TOLD cards. Assists in preparing an aircraft destruction plan in the event the aircraft is disabled in hostile territory.
Communication Systems Operator (CSO)	Prepares the Communications Execution Operating Instruction (CEOI) in response to the threat environment. Resolves C&C communications security matrix needed to coordinate all mission activities. Determines the SAFE and plans the E&E plan in the event the aircraft becomes disabled or is downed in hostile territory.

Since students may employ different strategies in planning their mission, the mission execution period may be envisioned for our purposes as the integration of smaller, discrete mission phases composed of several operational objectives. Within each of these phases, each crewmember is required to perform a series of complex tasks. Moreover, the crew must perform a series of difficult duties as a collective unit to ensure the successful accomplishment of the particular mission objectives. Below, we describe each of these mission phases, illustrating the means by which each crewmember, and the collective crew, might work to successfully accomplish these objectives. Our purpose here is to paint a general picture of how the crew might execute the simulated CMT scenario they have prepared for during the previous period.

The first mission execution event is the **Low-Level (LL)** tactical operations phase. The mission objective is to conduct NVG low altitude flight en route using proper tactical mission management procedures (e.g., very low altitude flight, high-speed maneuvering, terrain masking, optimal tactical routing) for the threat environment. In this phase, the AC physically flies the aircraft using NVG low-level altitudes and procedures along the intended route of flight, under the steering guidance provided by the LN. The CP assists the LN with route navigation by confirming the NVG visual reference points that have been identified from the mission charts,

navigation systems information, and digital scan radar and/or IDS presentations. The CP also assists the AC by continually cross-checking the relevant flight instruments for proper altitude, airspeed, and attitude indications, and advising the AC of unsafe deviations and corrective action where necessary.

In this mission phase, the AC and CP are the "eyes outside" to the visual world for the LN who is not on NVGs. In that respect, the LN maintains a continual dialogue with the AC and CP to confirm that the pilots are communicating what is expected, and that they are flying to the correct visual reference point. Additionally, the LN works to overcome a major known NVG limitation, distance estimation error, by constantly "calibrating" the pilot's eyes on their distances from these visual reference points.

During the LL phase, the RN is primarily responsible for continual assessment of the overall threat situation, and informing the crew of or performing those actions required to defeat a threat encounter. To that purpose, the RN coordinates with the LN for alternative steering commands away from threat locations, and with other crewmembers on the performance of a threat maneuver or a weapons flyout status. It is very likely that the crew will encounter an unplanned threat during this mission phase. Even if the mission tactics plan was prepared perfectly, and the crew was able to avoid or successfully mask from all known threats, the instructors will often program unscripted threats into the flight path to force the crew's spontaneous response to a hostile intent or weapons flyout.

It is also possible that the crew may incorrectly apply their planned tactics in this situation, perhaps suffering aircraft damage as a result. In this case, the FE is an "eyes inside" crewmember who keeps the aircraft flying from an engines and power perspective, and advises the AC of malfunctions, battle damage and effect, and any corrective actions necessary. The AC, CP, and LN continue to coordinate those activities necessary to fly the aircraft out of further harm, and yet continue toward the next mission object. The RN works to coordinate those tactics necessary to beat the threat, while the FE keeps the aircraft flying. All the while, the CSO is communicating with several C&C elements to keep them appraised of the current situation and mission progress.

This phase, as well as the others, also includes several scripted occurrences of irrelevant communications and unforeseen events that, like the real world, occur in flight. The scenario's intent is to insert a number of distracting events throughout the mission that requires the CSO (and others) to obtain and filter relevant information, determine the mission impact, and solicit alternative COAs in response to these changed mission conditions. For example, one instructor might role-play the ABCCC command element, and report that one of the helicopters expected for the AR has ditched while enroute to the objective area. This would require the crew to determine the degree to which this change impacts their primary mission activities, or whether they are required for further on-scene Search and Rescue support. Several outcomes are possible, and the crew must work the issue through to its correct conclusion. If an incorrect conclusion is produced—for example, the crew decides it is appropriate to divert from its original mission tasking—the instructor might indirectly intervene to steer the crew back to the original mission objective by role-playing ABCCC's refusal to grant their mission divert clearance.

The next mission phase is **Air Refueling (AR)**. In this phase, the mission objective is the successful conduct of tactical in-flight AR operations for multiple MH-53J Pave Low helicopters within prescribed time, course, and altitude constraints in a threat environment. Again, the AC is physically flying the aircraft in order to execute the AR operation's rendezvous, join-up, and refueling procedures. The AC is accepting the direct guidance and control of the LN who is providing continuous steering commands based on navigation systems information and/or radar presentations, and the RN's regular interpretation of IDS images. Meanwhile, the CP continues to provide backup support for these activities, the FE prepares the aircraft for the fuel transfer operation, and the CSO provides constant status communications with the C&C elements and/or the helicopter parties. Upon completion of the AR operation, the aircraft is reconfigured for low-altitude flight operations and high-speed maneuvering requirements to meet the next mission objective.

The next mission phase is the **Airdrop (AD)** operation. The objective of this mission phase is to successfully conduct the CARP airland of SF personnel within prescribed time, course, and altitude constraints in a threat environment. In this phase, the AC is required to fly the aircraft with exacting altitude, airspeed, and heading parameters, as provided by the LN, in order to correctly position the aircraft for the AD operation. The CP assists the AC in this phase by continually providing cross-checks of the aircraft attitude, and advising of deviations and corrective action where necessary. The CP also monitors outside visual references to help identify the DZ, and determine the CARP offset aim points for run-in. The LN and RN are tuning and interpreting the digital scan radar presentation and IDS object sensitivity in order to identify the DZ, as well as configuring the navigation system's sensitive (e.g., "hot cursor") steering commands. The FE configures the aircraft for the AD operation (e.g., opens appropriate doors so that the simulated SF personnel may leave the aircraft), and configures certain systems to minimize damage if they fall under hostile fire while "exposed" in the AD operations' low altitude and slow airspeed requirements. The CSO coordinates for the final drop clearance and relays this information to the crew for the final drop decision which is made by the LN and AC. Upon completion of the drop operation, the aircraft is reconfigured to resume the high-speed, low-level operation previously described in order to reach the next mission objective.

The crew prepares to perform the final **Infil/Exfil (I/E)** operation required to transload the flag officer and the diplomatic negotiation team at the forward-deployed field hospital landing zone (LZ), and to evacuate their aircraft from the unsecured airfield. The objective of this mission phase is the successful conduct of covert insert and/or extraction at tactical landing sites for transload purposes within prescribed time, course, and altitude constraints in a threat environment.

In this phase, the AC is responsible for correctly positioning the aircraft for a Self-Contained Approach (SCA), where the on-board navigation systems are programmed using unique techniques to provide semi-precise, initial approach path, final approach, and missed approach navigation steering. The approach steering is coordinated with the LN, who interprets navigation information in the form of verbal steering commands that are confirmed on the flight instruments by the CP. The RN identifies the LZ aim point using the IDS presentation, and

confirms the LN's interpretation of the radar picture. The FE is the coordination link for the timely completion of all required checklist items and responses and monitors the final approach and landing speeds while confirming the aircraft's configuration for landing. Finally, the CSO coordinates the required final approach and landing clearances, and the transload procedures with any ground parties. Upon completion of the transload operation, the aircraft is reconfigured for immediate takeoff, and resumes the low-level operation to the final recovery airfield.

Table 4 provides a summary of these general mission execution roles and responsibilities. Again, these duties are not absolute and may vary depending upon crewmember experience, expertise, or interest. As with Table 3, Table 4 is intended to show that each crewmember is heavily involved in executing certain activities that must be collaboratively and effectively performed in order to accomplish the mission tasking.

Table 4. Crewmember Roles and Responsibilities During Mission Execution

Crewmember	Mission Execution
Aircraft Commander (AC)	Conducts each mission event briefing to coordinate or update objective details. Coordinates the separate activities of each crewmember into a integrated unit focused on objective accomplishment in an environment of dynamic changing conditions. Provides final Go or No-Go decisions to continue operations.
Copilot (CP)	Assists in interpreting flight chart annotations necessary for low-level NVG flight operations. Promotes the activities of each crewmember as a cohesive unit focused on successful objective accomplishment in an environment of dynamic changing conditions.
Left Navigator (LN)	Reads and interprets the Flight Chart annotations necessary for low-level NVG flight operations (e.g., correlating map features with radar or IDS presentations). Commands the Infil/Exfil SCA operation. Enters the mission data to program aircraft mission computers.
Right Navigator (RN)	Performs continuous threat capabilities analyses and executes the tactics plan. Re-computes the CARP and updates the airdrop plan for the LN. Coordinates updates to the AR rendezvous and join-up plan with the LN in response to dynamic condition updates.
Flight Engineer (FE)	Executes the aircraft fuel management plan. Re-computes the aircraft weight and balance data, and TOLD cards after each mission objective is completed. Coordinates completion of checklist items and ensures responses are verified.
Communication Systems Operator (CSO)	Executes the CEOI in response to the threat environment and mission conditions. Continually monitors the mission progress and updates the E&E plan as necessary. Filters mission information between the flight crew and C&C.

METHOD

This section describes the research methods and procedures that we used. First we cover the backgrounds of the SOF crews who served as research participants. Second, we present the logic underlying the quasi-experimental design that was used. Next, we discuss the instruments that we used to collect the empirical data. We then describe the procedural steps that were followed in collecting data from four primary sources: student questionnaires, instructor questionnaires, researcher structured observations, and instructor/operator station (IOS) pages.

Participants

Thirteen MC-130P SOF aircrews (79 crewmembers total) were observed during their week-long visit to KAFB for ART. Observations were made over an 8-month period (March-October 1996). Two of these crews (Crews #1 and #8) were eliminated from subsequent analyses because they were unable to fly the simulated mission due to simulator malfunctions. Thus, 11 crews (67 crewmembers) were included in the analysis.

The typical make-up of an MC-130P crew for ART consists of six members: two pilots, two navigators, one FE, and one CSO. In this study, crew size varied from 5-7 members because two crews trained with an extra CSO for the observed mission while one crew did not have a CSO at all. However, the modal crew size was six. The distribution of crew size across the 11 participating crews is displayed in Table 5.

Table 5. Crew Size of Each Participating MC-130P Crew

Crew No.	Crew Size
2	6
3	6
4	7
5	7
6	6
7	6
9	6
10	6
11	5
12	6
13	6

As shown in Table 6, the participants were, on average, very experienced SOF personnel. Nevertheless, four crewmembers had only 100-200 hours prior flying experience in the MC-130P, with one crewmember reporting zero hours. (This individual was a highly experienced pilot with 1,550 hours in MC-130H models who was just "filling in" for the week with the MC-130P crew.) However, none of these inexperienced crewmembers served in the same crew during the study.

Table 6. Crewmember Flying Experience Summary

	Frequency	Mean	Minimum	Maximum	Standard Deviation
Age	67	34	25	48	5
MC-130P Flying Hours	67	1286	0	7550	1231
Total Flying Hours	67	3056	500	7550	1231
CRM Training Hours	67	37	0	200	37

In addition, the crewmembers within the various crews hailed from different SOF squadrons as indicated in Table 7, with both enlisted and officer ranks well represented (see Table 8). Appendix A presents a detailed demographic summary for each crew. These factors included: age, MC-130P flying hours, total flying hours, CRM training hours, hours of experience in the mission AO, distribution of ranks, and squadron affiliation.

Table 7. Squadron Affiliations of the Participating MC-130P Crewmembers

Squadron	Frequency
Other	6
5th SOS	10
9th SOS	16
67th SOS	12
17th SOS	23

Table 8. Distribution of Participating MC-130P Crewmembers by Rank

Rank	Frequency
Ltc	3
Maj	6
Capt	35
Msgt	5
Tsgt	7
Ssgt	10
Amn	1

Highly experienced Mission Training Support System (MTSS) MC-130P instructors also participated in this effort as supplemental performance evaluators. Each crew position was paired with an instructor during the entire week of ART, and this instructor was present during Day 5 training. Following observation of the Day 5 mission, every instructor completed an IRI whose specifics are described later.

Design

Five features were considered central to the design of the present study:

(1) quasi-experimental observation method;

(2) independent assessments of team coordination and mission performance;
(3) robust team assessment measures;

(4) multimeasure, multimethod (MM-MM) mix of variables; and

(5) behaviorally anchored ratings scales (BARS).

Quasi-Experimental Observational Approach

The present study collected data in a naturalistic observational setting. There were several reasons for this choice. First, we were able to capitalize on ongoing MC–130P ART using a combat mission scenario that was already in place. We worked with the AFSOC training community on a not-to-interfere basis and, as a result, had access to a highly experienced, volunteer subject pool. Second, use of a naturalistic observation paradigm offered the advantages of operational relevance (external validity) and a clear-cut application of team mission performance and coordination principles. Third, this approach provided us with the ability to immediately fold back lessons learned into the 58 TRSS ART program, without the lag time so often associated with laboratory research efforts.

Although we did not explicitly manipulate any experimental variables, we were nevertheless able to examine key relationships by using post hoc groupings of the data we collected. For example, we examined the effect of a crew's predominant squadron affiliation on team mission effectiveness. Consequently, some of analyses reported herein are based on a quasi-experimental, as opposed to a strictly correlational, approach.

Independent Assessments of Team Coordination and Mission Performance

Independent assessments of team coordination processes and team mission performance were also essential to the present approach. Specifically, independent collection of coordination data from one researcher and mission performance data from a second researcher helped ensure the validity of direct comparisons and avoided the artificially inflated correlations that stem from obtaining both sets of measures from the same rater. Using two individuals to make separate assessments—in conjunction with selected computer printouts—also enabled detailed accounts of both coordination process and performance behaviors. Each rater was able to focus all of his/her attention on their assigned dimensions.

A highly experienced, former AFSOC MC–130P operator was employed to collect coordination data; a second researcher (Ph.D. psychologist) and four ART instructors assessed mission performance. IOS-based performance measurement pages were also collected and evaluated at various points during the simulated mission. The resulting process-performance relationships were accordingly established from independent data sources.

Robust Team Assessment Measures

The study's measures of team mission performance and coordination focused on behaviors that were collectible, variable across crews, and operationally relevant. First, we considered the constraints of the training environment and resources available to determine behaviors that could be measured reliably. We oriented our measurement efforts on those behaviors that we could practically expect to collect on a weekly basis.

Second, we selected team behaviors that we thought were most likely to vary across crews. For example, many training scenarios are designed so all crews will satisfy the overall objectives

of the mission—successful launch, receiving fuel during the AR, meeting the time on target (TOT), navigating within prescribed accuracy levels, performing the designated infils and exfils, and so forth. Sole reliance on these mission outcome measures posed problems for a team effectiveness study as the nonvariance across crews, reflecting in essence a "ceiling effect," could yield negative results for any variable of interest. Thus, given our overarching objective of identifying the most effective MC-130P aircrews, we attempted to emphasize behaviors that maximally differentiate strong from weak crews. Our preliminary testing and SME-interviews provided invaluable insights regarding high payoff areas (e.g., the five T^2RM subprocesses) and potential behaviors on which to focus.

Third, the observed behaviors we selected were operationally relevant. Indeed, operational realism was one of the primary considerations in selecting the five T^2RM subprocesses (TM, SA, FA, TE, and C3) described in Table 1. In addition, crewmembers often complain about the "soft" topics (group cohesiveness, leadership) traditionally taught in CRM courses and their weak connection to the missions crews actually fly. The T^2RM subprocesses we examined attempt to bring crew coordination training closer to the CMT environment, including operationally relevant, behavioral indices of team coordination. These behaviors may then be folded back into training, providing crews with immediate and relevant feedback.

Multimeasure, Multimethod (MM-MM) Mix of Variables

The study of team coordination and mission performance is clearly a multifaceted problem. Hence, it is not surprising that a MM-MM mix of variables is required to achieve a comprehensive, systematic investigation of the topic. As used here, a MM-MM approach refers to employing a battery of objective (e.g., computerized timing and counts) and subjective (e.g., ratings) measures coupled with quantitative and qualitative methods of data analysis. From an experimental perspective, a MM-MM variable mix was advisable as it permitted us to cast a wide net in order to tap cognitive processes that may have been too complex had we used a single index. Logistically, too, the approach has appeal as it is fairly robust with regard to potentially devastating losses of partial data due to simulator malfunctions or subject-crew turbulence.

Referring back to Figure 1, one can see that to **fully** explore the links in the measurement model, a minimum of seven measurement instruments is needed. Further, even if a researcher elects to focus on only select portions of the model (e.g., process and performance links), a MM-MM mix of variables allows one to correlate process and performance measures as well as provide opportunities to assess select intercorrelations among different types of objective and subjective performance measures.

In the present research, the following methods and measures were used:

1. An SME rated and observed T^2RM processes across five mission phases. This was accomplished by using headsets to monitor mission execution and from over-the-shoulder observations during MP.

2. In a similar fashion, a second researcher rated and observed team mission performance.

3. Instructors rated individual crewmember and team performance across each mission phase.

4. Finally, select simulator performance pages were printed out as each mission phase was executed.

Behaviorally Anchored Ratings Scales (BARS)

BARS are formal rating instruments that contain written descriptions of the behaviors associated with each scale value. These descriptions function as referents or anchors, and aid evaluators in determining the quality of various dimensions. Referents or anchors can be the simple presence or absence of a behavior (e.g., prepared a mission execution checklist? yes/no) or the quantitative standards that must be met (e.g., executed drop within 30 s of planned drop time). The behavioral anchors serve as criterion standards by which the evaluators give their ratings, as opposed to preference-based, normative comparisons to other crews. This standardization is designed to promote reliability of ratings across evaluators and crews. In recent years, the BARS methodology has become more commonly used in crew coordination research. For example, the US Army has made extensive use of BARS in the evaluation of their aircrew coordination course (Grubb, Leedom, Simon, & Zeller, 1993; Grubb, Simon, Leedom, & Zeller, 1993).

We applied a BARS approach for assessing team mission performance and the quality of MP products. After extensive SME review, analysis, and testing, we arrived at a series of team performance BARS for the different mission phases as well as the flight charts and flight plans created during MP which made up our T-MPT. On the process side, a modified BARS approach was used for the T-MOT. These instruments, as well as the other instruments used in our research, are described in the following subsection.

Data Collection Instruments

In depicting our team performance measurement model, recall that Figure 1 displayed a series of ovals that referred to the instruments we used during the flow of training activities. The following paragraphs describe the purpose and scope of each instrument used in this research effort, along with pertinent examples to illustrate the information items that form its content.

Crewmember Background Survey (CBS)

The CBS is a self-report tool that captures relevant background information from each crewmember. The instrument's purpose is to enable us to build a descriptive profile of each crewmember's flight, operational mission, weapons system, and organizational experience. Besides requesting total flight experience information, the CBS asks for each crewmember's estimate of recent flight experience with the other crewmembers attending ART. Aggregated

across each crew, the CBS was used to create descriptive profiles at the aircrew-level (see Appendix A). This instrument was administered on the first day of ART, immediately upon crewmember completion of course registration and prior to the beginning of classroom training.

Team-Mission Observation Tool (T-MOT).

The T-MOT was an integral part of our total assessment strategy. This instrument was designed to aid in recording specific individual and team coordination behaviors that fell into distinct T^2RM subprocesses, and which occur during discrete mission phases. Measurement was accomplished using 5-point Likert scales and SME observations of critical coordination behaviors tied to a complex CMT scenario.

The T-MOT supported recording and analyzing both individual crewmember and aircrew team behaviors within the five key T^2RM subprocesses (TM, FA, etc.) across critical mission phases. The T-MOT structures an SME's first-hand observations of complex task performance during both MP and mission execution. An internally consistent and reliable "record by exception" measurement philosophy was employed for capturing instances of extreme crew coordination behaviors demonstrated during CMT. Once collected, content analyses were performed on the recorded behaviors to permit comparisons of frequency, quality, and/or intensity across teams. This qualitative analysis supplemented quantitative analyses performed on the rating data that were also produced with this instrument.

The primary data collection method used in the T-MOT was over-the-shoulder, structured observations, a method sanctioned by Air Force Instruction 36-2243 (AFI, 1994). This technique has been successfully used in previous MP and MR studies (Spiker & Nullmeyer, 1995a; 1995b). While there was a "script" to help our SME structure his observations, he was also free to record "by exception" activities in which attitudes, behaviors, and cognitions that seemed unusually strong or weak were noted. This technique was principally used in observing T^2RM subprocesses by our highly experienced SME. When performed by a trained SME, direct observations achieve respectable levels of reliability (Tourville, Spiker, Silverman, & Nullmeyer, 1996).

The T-MOT is divided into subsections devoted to a particular T^2RM subprocess within a particular mission phase. Specific YES/NO checklist items are provided within each subsection and assessed by the SME. Items include an explanation field available to record notable behaviors. Figure 2 displays an example item from the TM subprocess. Appendix B contains example items from the TE, FA, SA, and C3 subprocesses.

Additionally, we used a 5-point rating scale (1 = lowest to 5 = highest) to provide quantitative assessments across T^2RM subprocesses, crewmember positions, and mission phases. This technique proved to be a fairly efficient way to generate a large amount of data within a well-defined structure in which the observer used rules to assign ratings to specific attributes of T^2RM.

Time Management (TM): Involves the ability of the combat mission team to employ and manage limited time resources, so that all tasks receive sufficient time to be performed correctly, and critical tasks are not omitted.

1.0 An end-mission planning time should be indicated up front - most likely by an emergent "leader."
   a. Did any crewmember indicate the need for an end-mission planning time? .... YES/NO
   (Explain) ______________________________
   b. Was that time noted by all other crewmembers? .... YES/NO
   (Explain) ______________________________
   c. Did any crewmember designate activities to establish a proper balance between their own authority, time available, and crewmember participation? .... YES/NO
   (Explain) ______________________________
   d. Was adequate mission preparation time allocated for a comprehensive pre-mission briefing?.................. YES/NO
   (Explain) ______________________________

Figure 2. Example TM Item from the T-MOT.

The T-MOT included brief descriptions of each mission phase (see Figures 3-7) and each phase was assessed separately during Day 5 of ART. The phases were assessed in their naturally occurring sequence, as a series of mission events that occur up to, during, and immediately after the particular mission objective.

As shown in Figure 3, each crewmember's demonstrated behavior during MP was individually rated by our SME-observer, using the 1 to 5 scale, across all five T^2RM subprocesses. A similar format was used to rate the other mission phases.

Mission preparation (MP) procedures: The objective is to conduct mission planning and briefing activities that allow sufficient preparation of a comprehensive mission execution plan. This plan will be prepared with considerations for a medium threat environment, all major mission events and activities; and mission operations procedural constraints.

	AC	CP	Nav 1	Nav 2	FE	CSO
1. Situation Awareness						
2. Function Allocation						
3. Tactics Employment						
4. Time Management						
5. Command, Control, & Comm.						

Figure 3. Matrix of Ratings Used in the MP Segment of the T-MOT.

Figure 4 illustrates one of the measurement items from the T-MOT. This item was used to record the demonstration of C3 behaviors during the LL phase. As with the other items, the observer first indicated whether the behavior was present or absent; he then provided explanatory comments in the space available.

Low-Level (LL) tactical operations procedures: The objective is to conduct NVG low-level flight en route to specific mission events using proper tactical mission management procedures (altitude, airspeed, terrain masking, etc.) for a medium-threat environment.

2.0 (C3) CSO receives incoming message that (one) helicopter has ditched. The crew should spend <5 min dealing with the problem (including time for CSO to filter info). There need not be an excessive amount of discussion about the problem's solution.

a. Was this event handled by one focal crewmember (versus a full crew emphasis)? .... YES/NO
(Explain) ______________________________

b. Did the CSO filter the message appropriately ? .... YES/NO
(Explain) ______________________________

c. Were reasonable options presented for dealing with the message? .... YES/NO
(Explain) ______________________________

d. Was an appropriate decision (outcome) ultimately concluded? .... YES/NO
(Explain) ______________________________

Figure 4. Example of a C3 Item from the LL Segment of the T-MOT.

Figure 5 illustrates another measurement item from the T-MOT. This item was used to record the demonstration of TE behaviors during the AR phase.

Air refueling (AR) procedures: The objective is to successfully conduct tactical in-flight AR of (multiple) MH-53J Pave Low helicopters within prescribed time, course, and altitude in a medium-threat environment.

3.0 (TE) The AR should be completed early, so they can escape hostile airspace quicker. This also gives the crew additional flex time for later in the mission, when mission events get tight around LZ #2.

a. Did the crew exercise proper tactical refueling (phase) management procedures? .... YES/NO
(Explain) ______________________________

b. ARCP ATA ______________ - Acceptable? .... YES/NO
(Explain) ______________________________

c. EAR Time ______________ - Acceptable? .... YES/NO
(Explain) ______________________________

Figure 5. Example of a TE Item from the AR Segment of the T-MOT.

Figure 6 depicts a TE measurement item from the AD phase.

Airdrop (AD) procedures: The objective is to successfully conduct CARP airland of SF personnel within prescribed time, course, and altitude constraints in a medium-threat environment.

4.0 (TE) Technical proficiency of airdrop should be rated by exception.

a. Were there any problems noted during the airdrop procedure? .... YES/NO
(Explain) ______________________________

Figure 6. Example of a TE Item from the AD Segment of the T-MOT.

Figure 7 presents another TE measurement item. This one is from the I/E phase.

Infil/Exfil (I/E) procedures: The objective is to successfully conduct covert infil and/or exfil at multiple tactical landing sites for transload purposes within prescribed time, course, and altitude constraints in a medium-threat environment.

5.0 (TE) Crews can have serious problems making the approach due to poor visibility and NVG conditions.	
a. Did the crew have problems with the approach?	YES/NO
(Explain) ______________________________	

Figure 7. Example of a TE Item from the I/E Segment of the T-MOT.

Lastly, the T-MOT included a summary section (see Figure 8) where each crewmember and crew as a whole were rated on the five T^2RM subprocesses by each mission phase. This was followed by a summary table where overall crew coordination for each crewmember and crew was assessed (bottom section of Figure 8).

OVERALL: Summarize each crewmember's, and the crew's, demonstrated overall CRM behaviors, during each mission phase as indicated, from 1 to 5 (Use rating scale).

OVERALL (CRM) Rating	AC	CP	LN	RN	FE	CSO	CREW
1. Mission Preparation (MP)							
2. Low-Level (LL)							
3. Air Refueling (AR)							
4. Airdrop (AD)							
5. Infil/Exfil (I/E)							

OVERALL (CRM) Rating	AC	CP	LN	RN	FE	CSO	CREW
FINAL ASSESSMENT							

Figure 8. T-MOT Overall Crew Coordination Assessment Section.

Team-Mission Performance Tool (T-MPT)

The T-MPT was designed to aid in evaluating the mission performance that was demonstrated during the tactical MP and execution phases. This instrument provided a structured method for the second researcher to rate the quality of individual- and team-generated mission products developed during the MP phase, as well as to provide anchored ratings of demonstrated performance across the mission execution phases. The quality of the mission products developed by the aircrew team or individual crewmembers is one index of team mission performance.

Figure 9 depicts a BARS item from the T-MPT that was used to rate mission flight charts developed during the MP phase. The scale was used to assess the quality of the flight charts generated by the LN, RN, and the pilots.

1	2	3	4	5
- Poor. - Incomplete data. - - General lack of documentation. - General quality of preparation is poor.	- Marginal. - Insufficient or inaccurate documentation. - Unaccounted for discrepancies between LN, RN, and CP charts. - Deviation plan minimally prepared. - Marginal quality.	- Adequate. - Threats plotted. - Most threat rings plotted. - Deviation plan clearly drawn. - Appropriate altitude considerations made. - Required checklist annotations made.	- Outstanding. - Threat rings plotted. - Deviation plan clearly drawn and visible for NVG conditions. - Appropriate altitude and terrain considerations made and explicitly represented in the deviation plan.	- Exceptional. - Threat contour shading provided. - Deviation plan and threat information highlighted for NVG conditions. - Documentation in excess of minimum requirements. - Threat labels.

	Score	Explain
LN Mission Chart		
RN Mission Chart		
Pilot Mission Chart		

Figure 9. Example BARS Item from the MP Portion of the T-MPT.

Figure 10 presents a BARS item from the T-MPT that was used to score performance during the AR phase. BARS were also used to assess LL, AD, and I/E performance. As with the planning products described above, the proficiency of mission phase behavior demonstrated by the aircrew team is another index of team mission performance.

Instructor Rating Instrument (IRI)

The IRI was designed to capture the unique perspectives of training instructors as they rated the demonstrated performance of their own trainees in the context of overall crew performance. For the MC–130P WST, separate instructors train the pilots (AC and CP), navigators (LN and RN), CSO, and FE. Each crewmember was assessed by their instructors using a YES/NO checklist and a 1-5 Likert scale. These items and ratings covered issues of demonstrated MP and mission execution performance that were relevant to that particular trainee's crew position. In other words, each IRI was specifically designed and tailored to assess the particular instructor's student-crew position roles and responsibilities throughout the mission.

Secondarily, the IRI was designed to capture the instructor's unique subject-matter expertise and perspective by asking for separate ratings of their individual students, as well as the aircrew team as a whole, across mission phases. In this manner, another index of team mission performance was provided that was independent of the assessment provided by the researchers armed with the T-MPT and T-MOT.

AIR REFUELING

1	2	3	4	5
- Poor time control to ARCP. Arrives at ARCP earlier than 1-minute prior to planned ARCT. - Poor time control to ARCP. Arrives at ARCP greater than + 1 minute (or more) late to ARCP	- Minimal time control to ARCP. - Arrives at ARCP in window of from 1-minute to 1-second earlier than planned ARCT. - Unexplained maneuvering off refueling track.	- Adequate time control to ARCP. - Arrives at ARCP in window of from 30-seconds to 60-seconds later than planned ARCT. - Maintains refueling track.	- Outstanding time control to ARCP. - Arrives at ARCP in window of from 15-seconds to 30-seconds later than planned ARCT.	- Exceptional time control to ARCP. - Arrives at ARCP in window of from on-time to 15-seconds later than planned ARCT.

Was the AR operation successful? .... YES/NO

Explain ____

Figure 10. Example BARS Item from the AR Portion of the T-MPT.

Crewmember Self-Assessments (as part of the TMAQ2)

In addition to post-ART CRM attitude assessments (analyzed in Spiker, Silverman, Tourville, & Nullmeyer, in press) the TMAQ2 included a section that had questions regarding the crewmember's perceptions of his crew's mission readiness, mission confidence, coordination, and performance. This instrument was administered immediately upon the student's completion of his/her ART requirements.

Procedure

The instruments described above reflect the four primary sources of data for this research effort: (a) student questionnaires, (b) instructor questionnaires, (c) structured researcher observations, and (d) IOS page printouts. Procedural steps and schedule for collecting data from each of these sources are detailed below.

Student Questionnaires

Following the aircrews registration for ART, researchers administered the CBS and the TMAQ1. During any given week of training, various crews in addition to MC-130P crews arrived for ART. The CBS and TMAQ1 were administered to all of the crews who showed up en masse, which were sometimes as many as 40 crewmembers. Prior to administering the questionnaire, one of the researchers briefly described the research project and focus, the purpose of the information, and the researchers' roles in the upcoming days of ART. The researcher then distributed the questionnaires and remained available for questions or explanation until the trainees completed the CBS and TMAQ1. The entire process took approximately 30 minutes, which had been formally scheduled into the ART curriculum.

Following the simulator mission (their last training event) on Day 5 of ART, the researchers administered the TMAQ2, which included the identical attitude questions from the TMAQ1 with some additional self-assessment questions regarding their individual and crew coordination and performance for that dayís mission. The TMAQ2 was usually completed prior to instructor/crew debriefs of the mission. The total time for the students to complete the TMAQ2 ranged from 15 to 25 minutes.

Instructor Questionnaires

MP and mission execution performance data were collected from instructors using the IRI. The IRIs were distributed to each instructor at the beginning of the MP session for the Day 5 mission. As mentioned, each IRI was customized with crew position-specific checklist items and phase-specific performance ratings. The IRI also included two overall crew performance and coordination questions. Instructors usually filled out the questionnaires in two stages—completing the MP performance questions immediately following the planning session and the mission execution section following the simulator mission (e.g., while the students completed the TMAQ2). Instructors took approximately 10 minutes (total) to complete the IRIs.

Early on in the data collection process, we realized that the instructors were often "double-booked," i.e., had other duties assigned concurrently with their training duties. This meant that some instructor crew positions were not present during planning. When this happened, these instructors would only complete the mission execution portion of the IRI. This did not impede our research efforts, though, as our main source of performance data came from the researcher-structured observations discussed below.

Researcher-Structured Observations

Researcher observations were the primary source of process and performance data, with one researcher responsible for collecting process data and the other responsible for performance data. The process data were recorded on the T-MOT by a highly trained, former MC-130P navigator. During MP, this individual served as a *participant-observer (P/O)*. This relationship was deemed appropriate as our SME possessed a comprehensive understanding of current SOF doctrine and extensive flight, training, and simulation experience in SOF operations through training exercises and operational missions. In addition, the P/O approach has been successfully used in other team training research realms (e.g., Oser, et al., 1996). The P/O's primary responsibility was to perform data collection tasks (observer) using the T-MOT. Secondarily, he served as the senior "controller" (participant) for such items as professional presentation of the training materials, development of the scenario script, role-playing as liaison officer with outside (simulated) agencies, and providing mission debrief support. The simulator training instructors collaborated with our P/O, and were also responsible for either controlling the computer simulation and role-playing additional higher C&C functions.

During mission execution, the SME-researcher observed and monitored crews from an intercom station located outside the MC-130P WST. The intercom station was situated in front of four instructor-operator screens which repeated the instructor inputs from inside the MC-130P

WST. From this vantage point, the SME-researcher was able to make informed observations and assessments based on personal knowledge and expertise concerning the mission, coordination performance, and monitoring instructor inputs.

The T-MOT's items were organized by mission phase and followed the prescribed sequence of mission events. Overall ratings and summary assessments were filled in immediately following the simulator mission. The completed T-MOT was reviewed early the following week to ensure that no assessment items were omitted. On rare occasions during this review, a change or two would be made to an overall assessment due to recognition of a transcription error or something notable having been overlooked.

Performance data were collected similarly. However, the researcher who collected performance data did not serve as a P/O during MP. She merely observed crew performance keeping in mind the criteria established in the T-MPT. Her notes and observations captured such items as: the number of briefings each crew gave, the contents of the briefings, who performed the briefings, the number of charts created, etc. All of these notes facilitated post-mission completion of the T-MPT. Similar types of notes were taken during mission execution (e.g., time of AD, time to complete AR). The researcher was located in the SNS collocated with the Instructor CSO and CSO while the mission transpired. From the SNS, she monitored the crew communications, flight path, and threat laydown. It was also from this location that various IOS pages were selected and printed out (see next subsection), to aid in later completion of the T-MPT.

At the conclusion of the simulator mission, the researcher collected all products (flight plans, charts, SCAs, execution checklists, etc.) that the crew created for the mission. These materials were then used to complete the BARS items on the T-MPT.

This combination of materials—notes, IOS pages, and crew products—was collectively evaluated using the T-MPT. For example, AD performance was evaluated using the BARS for AD where the actual performance was checked using the IOS ground track map (GTM) page, the prepared chart, and the recorded drop time. Besides rating the mission phase, the core products (flight plans and flight charts) were rated using a BARS. The quality and quantity of additional products and briefings were also evaluated using the T-MPT. Due to the classified nature of the mission and materials, the products were destroyed and the charts were erased once assessments were completed.

IOS Pages

As mentioned above, the primary purpose of printing out selected IOS pages was to aid the researcher in assigning the behaviorally anchored performance ratings (e.g., compare planned ground track to flight path actually flown) to each crew. The following IOS pages were printed out during the mission: (a) GTM pages at each waypoint; (b) AR pages at initial point, control point, and at least two during the contact phase; and (c) GTM pages during approach and while landing for the I/E. The GTM pages for the AD, AR, and I/E waypoints were the most critical for completing the T-MPT.

RESULTS

T^2RM Process and Team Mission Performance

Rating Data Structure

Table 9 depicts the data structure for the process and performance ratings. Recall that all process ratings were obtained from the T-MOT whereas the performance data came from the T-MPT, in which separate raters were used for the two instruments in all cases. An overall **process** rating and specific process ratings for SA, TE, TM, FA, and C3 were generated for the whole mission and the five mission phases (MP, LL, AD, AR, and I/E), resulting in the 6 x 6 matrix of process ratings depicted at the top of Table 9. Mission **performance** ratings were provided for the five mission phases, and a total mission performance rating was generated by calculating the sum of the five phase-specific ratings for each crew, a value that we will refer to as PerfSum, resulting in the six-element array of performance ratings, depicted at the bottom of Table 9. With respect to PerfSum, we used a sum of the five mission-phase performance ratings because the skills required in each phase are so different that we did not believe that an overall rating would be reliable or valid. The PerfSum variable was, itself, multivariate in nature since it was based on a composite of MP performance (as determined by ratings and tallies of key mission planning products, the details of which are described later) and the overall performance ratings obtained for each phase of the mission (LL, AD, etc.).

Table 9. Data Structure for Ratings of T^2RM Subprocesses and Combat Mission Performance

Process Ratings	**Whole Mission**	**Mission Preparation**	**Low Level**	**Air Drop**	**Air Refueling**	**Infil/Exfil**
Overall Process						
SA						
TE						
TM						
FA						
C3						
Performance Ratings	(PerfSum)	Phase-specific rating	Phase-specific rating	Phase-specific rating	Phase-specific rating	Phase-specific rating

Process and Performance Rating Correlations

The majority of analyses that we report in this subsection involve Pearson product moment correlations between various pairs of crew-level rating data associated with T^2RM processes and combat mission performance. These correlations are summarized in Table 10.

Before discussing the results, we must first describe some conventions for interpreting the contents of this rather complex summary table. We use the first column to describe the types of analyses that are contained in the subsequent cells of that row. Column 2 of the table refers to correlations involving pairs of performance and process ratings reflecting the whole mission and the remaining five columns reflect ratings of behaviors performed within specific mission phases.

The rows in the table correspond to categories of correlations that cross mission elements. The top row depicts correlations between our most global process rating (the overall process rating for the entire mission) and the six performance ratings. The second row summarizes correlations between our most global performance rating, PerfSum, and the overall process ratings generated for each mission phase. The third row summarizes correlations between phase-specific overall process ratings and phase-specific performance ratings. The remaining five rows reflect correlations between performance ratings and each of the five subprocess ratings within each of the six mission categories. It should be noted that the first column contains correlations between PerfSum, which, as mentioned, was computed as a sum of the five mission element ratings, and a summary rating for each subprocess that takes all mission phases into account.

Table 10. Correlations Among Ratings of T^2RM Processes and Combat Mission Performance

Process/Performance	**Whole Mission**	**MP**	**LL**	**AD**	**AR**	**I/E**
Overall Process x Performance	.86* (.89)*	.78*	.74*	.39	.52	.41
Phase-Specific Process x Performance Sum		.78*	.57	.79*	.75*	.77*
Phase-Specific Process x Phase-Specific Performance		.68	.46	.54	.70	.67
SA Subprocess x Performance	.76*	.48	.47	.59	.28	.65
TE Subprocess x Performance	.78*	.27	.06	.54	.81*	.55
TM Subprocess x Performance	.83*	.41	.36	.66	.51	.64
FA Subprocess x Performance	.75*	.22	.61	.55	.55	.60
C3 Subprocess x Performance	.08	.14	.09	.32	.37	.30

Experiment-wise and nominal criterion levels for significance testing
*$p_{EW}<.05$, $p_{NOM}<.001$ Bonferroni adjustment assuming 46 tests; critical r = .74

Within this structure, the most basic question we ask is whether there is a statistically significant relationship between mission performance (PerfSum) and overall crew T^2RM across the entire mission. The first row, first column depicts the correlations between the overall rating of crew coordination for the whole mission and the rating of crew performance for the total

mission (PerfSum). Outlined in bold, this whole-mission T^2RM by PerfSum correlation is the single most important analysis in the table, as it provides our most global, and hopefully most robust, assessment of the T^2RM process-CMT performance relationship.

To further explore the relationships between process and performance, we looked within the five primary mission phases. Our data structure allowed three ways to view phase-specific process and performance relationships: expand performance ratings to reflect individual mission phases and correlate with the whole mission T^2RM rating (Row 1), expand process ratings and correlate with PerfSum (Row 2), or expand both (Row 3).

The five entries on the right-hand side of the top row depict correlations between the whole-mission, overall process rating, and the five performance ratings for specific mission elements. For this row, the five column headings which contain the analytic results—MP, LL, AD, AR, and I/E—reflect the origin of the performance ratings.

The second row in Table 10 depicts the correlations between phase-specific overall process ratings and PerfSum. The five column headings which contain the analytic results now refer to the phase in which the overall process measure was taken, not performance. The first data cell in that row has been shaded out since its combination is identical to the corresponding cell in the first row (i.e., overall process and overall performance).

The third row in Table 10 follows a similar logic to that in the first and second rows. This time, however, the values refer to correlations between phase-specific process ratings and phase-specific ratings of mission performance. Thus, the five mission phase column headings now contain ratings in which **both** process and performance are phase-specific.

The correlations in the lower part of the table explore the impact of T^2RM process further by considering the relationships between the various T^2RM **subprocesses** and the corresponding performance rating. The five lightly shaded cells in the first column depict the correlations between each of the overall subprocess ratings (i.e., assessed across mission elements) with total mission performance, or PerfSum. The remaining 25 cells contain the most detailed view of the process-performance relationship. They depict the correlations between each subprocess—within each mission phase—with the corresponding performance rating for that mission phase.

Statistical Testing Considerations

Because all tests reported in this section use crew as the unit of analysis, our total N of 11 and the resulting 9-degrees-of-freedom (i.e., for t-tests, df = N-2 = 9) seem rather small to achieve the statistical power that one would like to establish a strong process-performance relationship. However, the 11 crews in our sample actually constitute a substantial percentage (26) of the population of approximately 42 SOF MC-130P aircrews that go through ART each year. Consequently, because we sampled a sizable proportion of the population, we are able to reduce our estimated variance of the sample mean by using a finite-population correction coefficient (Winkler & Hays, 1975). The correction coefficient decreases the observed sample variance by the square root of (N-1)/N-n, where N is the population size and n is the sample size.

In our case, the reported t-values below have been increased by 20%, reflecting a 1.2 finite-population coefficient multiplier.

Due to the exploratory nature of many of our research questions, and the need to perform a large number of statistical tests, we used a Bonferroni adjustment as a way to keep our overall, or experimentwise, alpha level from exceeding the desired (nominal) level. The Bonferroni technique is a conservative, though effective, way to avoid inflating the alpha level (and hence the likelihood of a Type I error) by "snooping" through one's data to locate the largest effect (Harris, 1994). The adjustment is made by dividing the desired experimentwise alpha level by the number of tests that are performed in a given cycle of testing.

As shown at the bottom of Table 10, we have employed a conservative nominal alpha level of .001 to control for the fact that we are performing 46 statistical tests. Since all correlations are tested against a null hypothesis of 0, this corresponds to a critical t-value of 4.19 (df = 9, one-tailed). Given the finite population correction described above, this means that our reported correlations have to reach a criterion of at least .74 to be significant.

Primary Result - Overall T^{2}RM Process and Overall Mission Performance

Turning to the correlations in Table 10, we find that our primary hypothesis—a strong, positive relationship between overall T^{2}RM process and overall mission performance—is supported by the data. This is evident from the large correlation coefficient, .86 ($t = 6.143$, $df = 9$, $p < .05$, two-tailed), that appears in the upper left-hand cell of the table.

To appreciate the highly linear relationship between T^{2}RM process and mission performance, Figure 11 depicts the scatterplot between crew performance sum on the x-axis and T^{2}RM process rating on the y-axis. As is evident from the figure, the poorest performing crews did indeed have the lowest overall T^{2}RM process rating whereas the highest rated crews received the largest mission performance sums. The intermediate values also behave in a similarly ordered fashion.

Because ratings have a tendency to bunch in the middle of the scale, we performed a supplemental analysis to determine if an even stronger (i.e., more linear) process-performance relationship would materialize if rank orders were used. Recall that rank ordering formed part of the logic of the Povenmire et al. (1989) methodology, and we wanted to determine if a similar trend would be found here. To that end, our SME-researcher reviewed his extensive T-MOT ratings and observation notes for each of the 11 crews. Based on this review, he rank ordered the 11 crews according to an overall assessment of their T^{2}RM process effectiveness during the mission. Independently, the psychologist-researcher reviewed her notes and T-MPT rating data, and formed a corresponding rank ordering of crews on the mission performance side. The Spearman correlation coefficient between the two sets of rank orders was slightly larger, .89, and is of course statistically significant ($t = 7.064$, $df = 9$, $p < .05$, two-tailed). Figure 12 depicts a scatterplot of the crew T^{2}RM and mission performance rank orders.

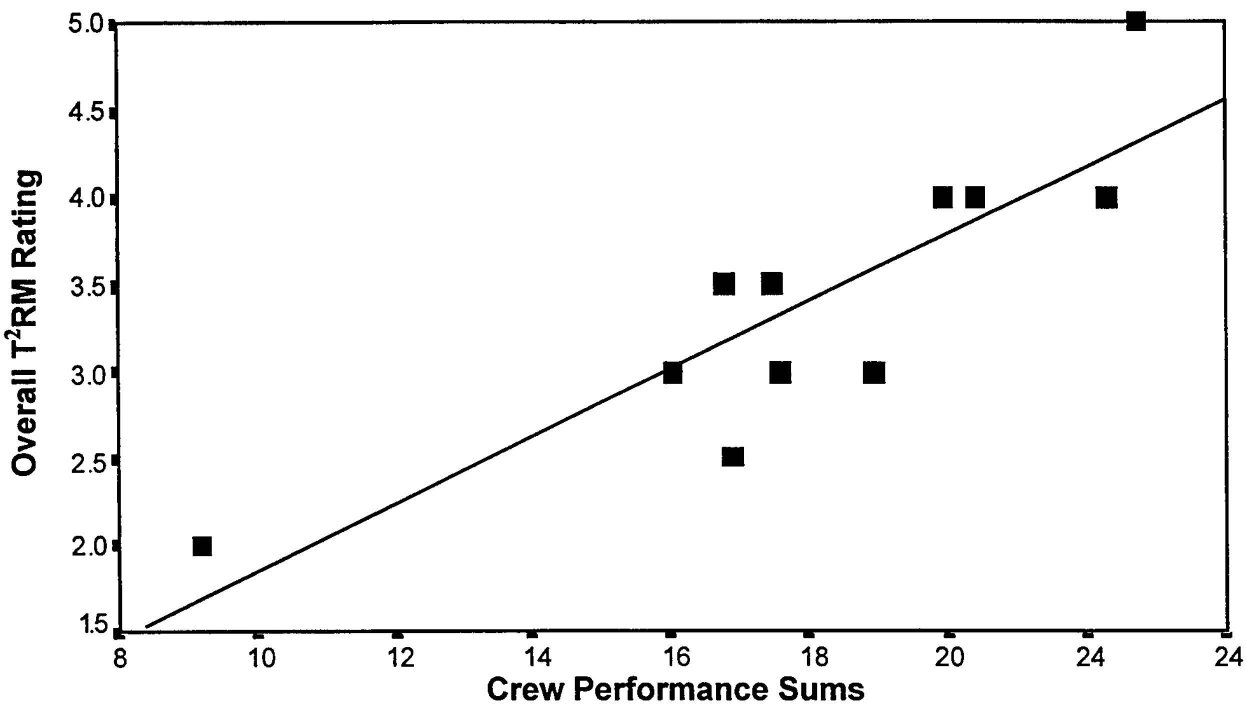

Figure 11. Scatterplot of Overall T^2RM Process Ratings and Mission Performance Sums for the 11 Subject-Crews.

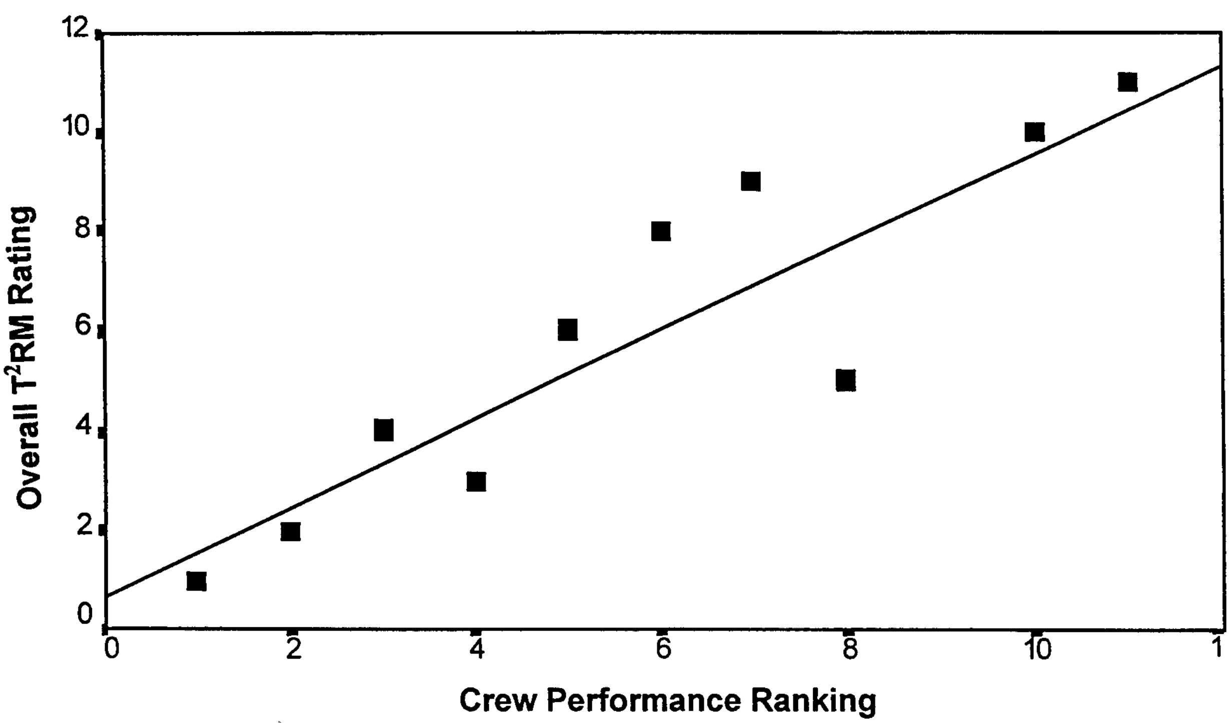

Figure 12. Scatterplot of Overall T^2RM and Mission Performance Rank Orders for the 11 Subject-Crews.

Secondary Results - T^2RM Process and Mission Performance by Subprocess and Mission Phase

Having established the fundamental relationship between T^2RM process and mission performance, the next step entailed pinpointing the subprocesses and/or phases in which the relationship is the strongest. As a first step, note that the five correlations in the top row of Table 10 depict the correlations between overall T^2RM process and the performance rating within each mission phase. As denoted by the asterisks, we see that the quality of the T^2RM process is significantly related to only two of the mission phases, MP and LL. Though trending positive, performance in the other three phases was not significantly related to T^2RM process. This finding shows that while the quality of the T^2RM process is important for performance, it is not uniformly so, but is instead localized in two discrete phases. It should be noted, though, that the large influence of these phases may be due to their relative durations compared to the AD, AR, and I/E phases. That is, both T^2RM subprocess and team mission performance ratings were based on sampling behavior throughout extended periods of time (i.e., 3 hours for MP, blocks of minutes throughout mission execution for LL), thus providing more representative and stable process and performance measures.

Examination of the correlations in the next two rows of Table 10 shows the influence that phase-specific T^2RM process exerts on overall performance (second row) and on phase-specific mission performance (third row). As seen in the second row, four of the phase-specific T^2RM process measures significantly predict overall mission performance. The only phase that failed to achieve significance was low-level navigation. When considered together with the discussion above, this finding suggests that the influence of T^2RM process on performance is not localized in a single phase, but rather is present throughout the entire mission scenario.

The gray-shaded cells in Table 10 depict the correlations that gauge the strength of the linear relationship between each of the five overall T^2RM subprocesses and overall mission performance (i.e., the PerfSum variable). As can be seen, four of the elements were statistically related to mission performance, with only C3 failing to achieve significance. The pattern of results in these cells clearly suggests that our decomposition of T^2RM into its constituent subprocesses was successful in identifying those factors having a strong impact on performance. Interestingly, the relationship between C3 and mission performance was near zero. In the concluding section, we will discuss the implications of this finding for interpreting some of the previous CRM literature.

Tertiary Results - T^2RM Subprocess and Mission Performance by Mission Phase

The lower right quadrant in Table 10 (outlined in bold) breaks down the analysis still further, as it comprises a 5 x 5 matrix of correlations between each phase-specific T^2RM subprocess rating and its corresponding phase-specific mission performance rating.

While all of the correlations were positive, and some even quite large, only the correlation between the rating of TE and mission performance during the AR phase proved significant ($t = 4.97$, $df = 9$, $p < .001$, one-tailed). Though our statistical tests cannot substantiate this, there is some evidence in the table to show that the T^2RM subprocesses exhibit differential effects across mission phases. One line of evidence for this differential sensitivity comes from a series of multiple regression analyses (MRA) that we performed across the five phases. In each case, the analysis showed that beyond the first or second highest correlated T^2RM subprocess (e.g., TE for AR), not much variance is accounted for by including additional subprocesses in MRA equations to predict mission phase performance.

This trend is also evident in the pattern of correlations themselves. As we examine each column, we first see that the T^2RM subprocess most strongly associated with the MP phase is SA, with a smaller contribution by TM. The main T^2RM subprocess associated with LL is FA, with some impact of SA. The T^2RM subprocess most strongly associated with AD performance is TM, although SA, TE, and FA also exhibited high positive correlations. Besides TE, other T^2RM subprocesses that influenced AR performance were TM and FA. Finally, I/E performance was associated with fairly large (though nonsignificant) correlations by all of the subprocesses save C3. Indeed, as can be seen in the bottom row of Table 10, C3 did not have any correlations above .40 with any of the mission phases. This is consistent with the low correlation that the C3 subprocess overall rating exhibited with overall mission performance.

Taken together, these results suggest that our subprocess measures of T^2RM have potential to be sensitive barometers of team mission performance. The implications of this sensitivity for training and field assessments of team effectiveness will be discussed in the concluding section.

Relationship of T^2RM to MP and Team Mission Performance

Although military doctrine is based on the premise that thorough MP is essential to mission success, there is surprisingly little empirical data to support this seemingly self-evident truth. We therefore performed several special analyses to gauge the effect of T^2RM on MP as well as the mediating effect that the quality of MP may exert on subsequent mission execution.

We begin the discussion by noting that as with overall mission performance, we did not have an overall rating of MP performance. Again, this reflects the diverse nature of the behaviors, skills, and information that are employed throughout this phase. Instead, our psychologist-research reviewed her notes and ratings from the T-MPT to extract 10 indices of MP that were applicable to all crews. These were: quality of crew briefings, LN chart, RN chart, Pilot chart, LN flight plan, RN flight plan, Pilot flight plan, number of briefs, number of planning products, and quality of planning products. A Factor Analysis was then performed on these indices to identify the ones that maximally discriminated among the 11 crews. Five measures were extracted from this analysis: quality of crew briefings, total number of planning products, quality of planning products, quality of the LN's flight plan, and quality of the RN's flight plan. An overall MP performance score was then established for each crew by summing the counts and ratings for these five measures. This was the index we used for all subsequent analyses involving MP.

There are several lines of evidence in our data to support the importance of MP to CMT. First, recall that our overall assessment of T^2RM process was most strongly related to performance during MP, as its correlation was only slightly lower than the one with overall mission performance (.78 vs .86). Based on the analysis described above, this means that the aircrews who exhibited superior T^2RM, on average, gave better crew briefings, produced a larger number of high quality planning products, and had higher quality flight plans produced by both the LN and RN.

Next, if better T^2RM means more effective MP, does that preparation translate into better overall mission performance? In order to make this determination, a special analysis had to be performed. Recall that our index of overall mission performance was based on the sum of ratings from all **five** phases, including MP. If we want to determine the relationship between MP performance and overall mission performance, we must first remove MP rating from the global index sum. We accordingly recomputed mission performance as the sum of the ratings from the four mission execution phases, i.e., LL, AD, AR, and I/E. With this revised index, we then computed the correlation between MP performance and overall mission performance. The correlation in this case was .60, which approaches significance for a nominal alpha level of .01.

To get an indication of the type of T^2RM that is associated with better planning, recall that the lower part of the second data column in Table 10 depicted the correlations between each T^2RM subprocess and MP performance. Two subprocesses, SA and TM, stood out as having the strongest relationship to MP performance. The implications of this relationship for training are discussed in the concluding section.

Having established the overall relationship between MP and mission performance, we next wanted to determine the *specific* aspects of MP that had the largest impact on performance. We began by comparing the 42 measures of MP effectiveness identified during a previous study (Spiker & Nullmeyer, 1995b) with the content items from the MP segment of the T-MOT. Of these 42, 12 were judged as relevant to the particulars of our study, i.e., a CMT scenario involving a single WST. These are listed in the left-hand column of Table 11.

The 11 crews were then scored on the extent to which each of the 12 measures were present in the observations of notable MP behaviors recorded in the T-MOT. As a basic index of MP quality, we simply counted the number of different measures, out of 12, that were represented by one or more behaviors recorded in the T-MOT. Examples of behaviors that would be assigned to each measure are shown in the right hand column of Table 11. Since negative behaviors were also recorded in the T-MOT, a measure was scored as a -1 if it contained only instances of unacceptable performance. Theoretically, scores could range from -12 to +12. The observed range in our sample of 11 crews was -1 to 12. We then correlated these derived scores with the crew's rank order on overall mission performance. A fairly sizable and significant correlation, .71, was observed ($t = 3.02$, $df = 9$, $p < .01$). Thus, crews who exhibited positive behaviors on a larger number of these measures of effectiveness performed significantly better during the mission.

Table 11. Measures of Mission Preparation Effectiveness

Measure of Mission Preparation Effectiveness	Representative Data Item from the T-MOT
All planning personnel are effectively utilized.	AC asked all crewmembers for "what you need to do your job" and then got it for them.
A timeline is established for managing the planning process.	AC told crewmembers when they had to be completed with their planning tasks in time for the crew briefing.
Precise times are determined for accomplishing the key mission events.	Planned AR control time and route backwards from the AR control point. Determined optimal takeoff time from these.
High-quality crew briefings are given during various stages of planning.	After each crewmember briefs, the AC adds final comments for the crew's consideration.
Planning crew achieve an in-depth awareness of threat capabilities along the route.	To avoid threats, crew planned to fly very low altitude, terrain mask, and high speed (as necessary) maneuvering.
The plan is developed to an appropriate level of detail.	FE and CSO prepared the evasion plan of action (note: a level of detail not provided by many of the crews).
All information sources are checked for recency.	AC asked when Intel had last been updated.
Information is cross-checked for accuracy and the plan's assumptions are aggressively questioned.	AC questions the assumptions made in each crewmember's component plan.
Ground team and support asset requirements are incorporated into the overall plan.	AC modifies plan to incorporate considerations of helicopters for the transload.
Mission essential equipment is well thought out and incorporated into the plan.	Crew listed the minimum equipment needed to accomplish the mission, such as INS, chaff, flares, etc.
Planning assumptions are subject to extensive "what iffing."	Crew planned to "bump up" their airspeed if they encountered threats during the AR.
Planners incorporate their real world experience into the planning process.	Crewmembers related their own experiences in the AO as they developed the execution plan.

Taken together, these analyses support the view that (a) good MP is indeed strongly related to better mission execution, and (b) superior SA and TM are good indicators of the types of crews who will have produced a superior mission plan.

Determination of Team Mission Effectiveness

One of the objectives of our research program is to identify the structural and/or behavioral characteristics of effective aircrews. However, in order to make this identification, we must first have a way to unequivocally measure and then classify those aircrews who are truly "effective." Below, we describe an analytic technique that was used to construct an interval scale of aircrew effectiveness, from which we determined the most and least effective aircrews.

The analysis is based on a class of Thurstonian scaling methods are described in Guilford (1954). The premise of these analyses is that a set of scores can be transformed into interval z-scale if one assumes that the underlying scale from which original scores are derived is normally distributed. In our case, we assume that the rank orderings of the 11 aircrews' T^2RM and mission performance produced by our two researchers are normally distributed. Using Thurstone's method of rank order, we combined the two rank orders into a single scale by first summing and then averaging the rank order pairs (process and performance) for each of the 11 crews. We then rescaled each average so that the lowest crew was located on the zero-point of the scale.

The resulting scale of effectiveness for our 11 crews is depicted in Figure 13. Scale values range from a low of 0, for Crew #10, to a high of 3.52 for Crew #13. The scale values may be interpreted much as one would view any z-score. For example, looking at Figure 13, one may see that Crew #9 was 2 units more effective than was Crew #10. Similarly, Crew #12 was another full unit more effective than Crew #9. In each case, then, we have defined effectiveness as a combination of T^2RM and mission performance.

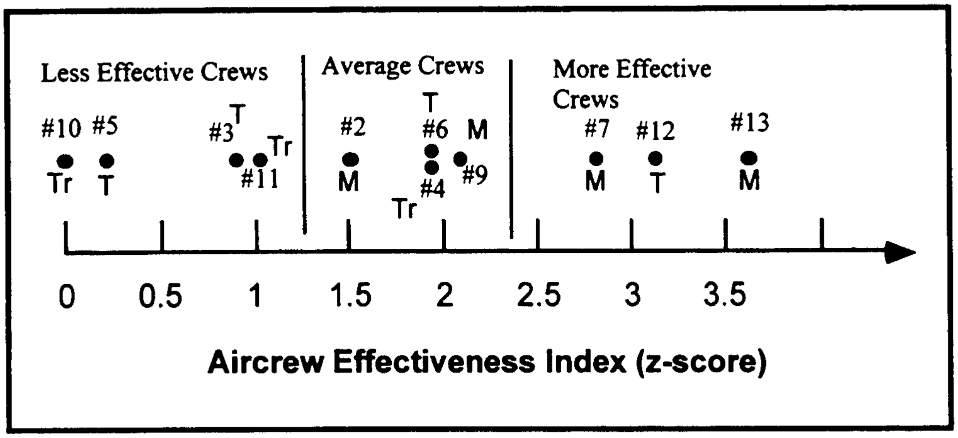

Figure 13. Interval Scale of Effectiveness and Type of Orientation for the 11 Participating MC-130P Aircrews.

Armed with this interval scale information, it is a fairly simple matter to establish criteria for labeling ineffective, average, and effective aircrews. These have been provided in Figure 13. Here, we see that four crews (#3, 5, 10, 11) have an effectiveness index less than 1, and have been classified as "less effective" crews. On the upper end, three crews (#7, 12, 13) have scale values well above 2, and thus are labeled "more effective." The remaining four crews are in the middle, and are accordingly referred to as "average." In the next subsection, we base our determination of the characteristics of more effective and less effective crews on these groupings.

To shed further light on the crews' distinguishing characteristics, each crew in Figure 13 has been labeled as "M," "T," or "Tr." These labels refer to the type of orientation that crews exhibited during MP and were assigned by the SME-researcher prior to the mission execution stage. Specifically, the labels refer to a Mission, Task, or Training orientation, respectively. Crews with a Mission orientation were always mindful of time requirements to complete MP, and did not get sidetracked with interpersonal tasks. On the other hand, crews that maintained a Task orientation throughout were more apt to get bogged down in details of MP, even if it meant reducing time for crew briefings at the end of the phase. Finally, crews that exhibited a Training orientation were always mindful that the mission for which they were preparing involved a training scenario, so were less likely to "go the extra mile" to complete the tasks required for a thorough job of MP. As can be seen in Figure 13, two of the three best crews exhibited a Mission focus where two of the four weakest crews were characterized as maintaining a Training orientation. The average crews represent a mix of the three types of crew orientation.

Characteristics of Effective Crews - Preliminary Assessments

As a prelude to developing a training intervention to promote more effective T^2RM, we must first determine those characteristics that are reliably associated with effective crews. In the following subsection, we present the findings from preliminary analyses of our data. We use the term "preliminary" because more in-depth analysis on a larger data set will, we think, be needed to fully delineate the more salient characteristics. Nevertheless, the analyses conducted thus far highlight several directions where future research is needed.

Structural Characteristics of Effective Crews - Team Demographic Variables

Due to the small number of crews in this research effort, it was difficult to identify any particular demographic variable having a significant relationship with effectiveness. Nevertheless, several interesting features are worth highlighting in the comparisons below, and should receive further study during follow-up research. We leave statistical testing of these elements to future work where a larger sample size may be obtained.

Squadron Affiliation. Visual inspection of the data suggests that a crew's predominant squadron affiliation is perhaps one of the strongest demographic predictors of mission effectiveness. For reasons confidentiality reasons, specific squadrons are not identified here. However, as seen in Figure 14, crews from "A" Special Operations Squadron (SOS) tended to be associated with low mission effectiveness scores, while crews from "D" SOS tended to be associated with high mission effectiveness.

Crew Size. Another finding of note is that crews trained under "artificial" sizes of either 5 or 7 crewmembers, rather than the organic 6-member crew, did not reach the upper levels of mission effectiveness. Indeed, the crew size-mission effectiveness plot displayed in Figure 15 shows that there is a continuum of mission effectiveness across the 6-member crews, suggesting that an organic crew size, by itself, does not guarantee superior mission effectiveness. However, it was only the 6-member crews that achieved the highest ratings of mission effectiveness.

Crew Structure. Crew "structure" is a term we use to refer to the typical manner in which crews were organized to promote interactions and information sharing. Structure was captured through careful analysis of the SME-researchers' notes and diagrams on the T-MOT. Three distinct types of crew structures were identified: (1) "Hub-and-spoke" (see Figure 16) crews as represented by crew #7, #12, #13; (2) crews with distinct dyads and triads initially but which "came together" as a crew (not necessarily as hub and spoke) over time, #2, #11, #4; and (3) crews with distinct dyads and triads that seemingly "never came together" as a crew over the course of training, as represented by crew #10, #9, #5, #3, #6. Due to the highly specialized skills required of each crew position, it is plausible that even the never-came-together structure might work as the required mission events could still be accomplished. However, it is interesting to note that the hub-and-spoke arrangement was characteristic of the three most effective aircrews. Moreover, the never-came-together structure aptly characterizes three of the four least effective crews.

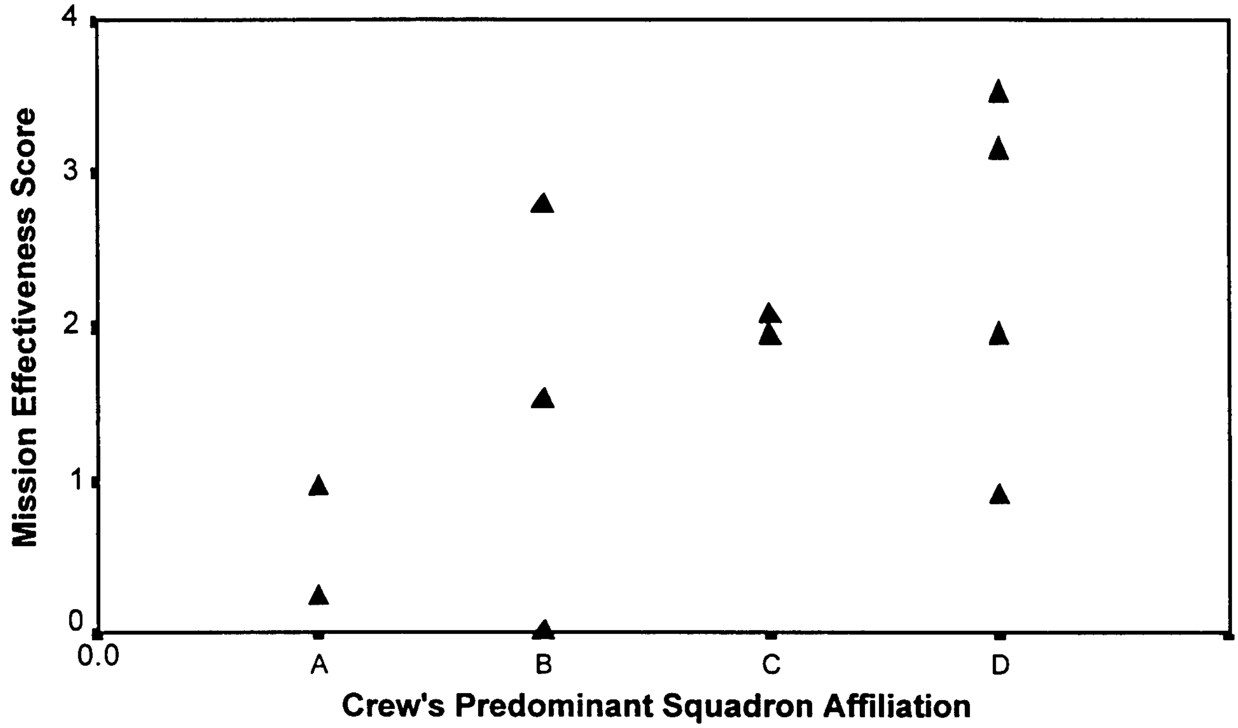

Figure 14. Relationship between a Crew's Predominant Squadron Affiliation and Mission Effectiveness.

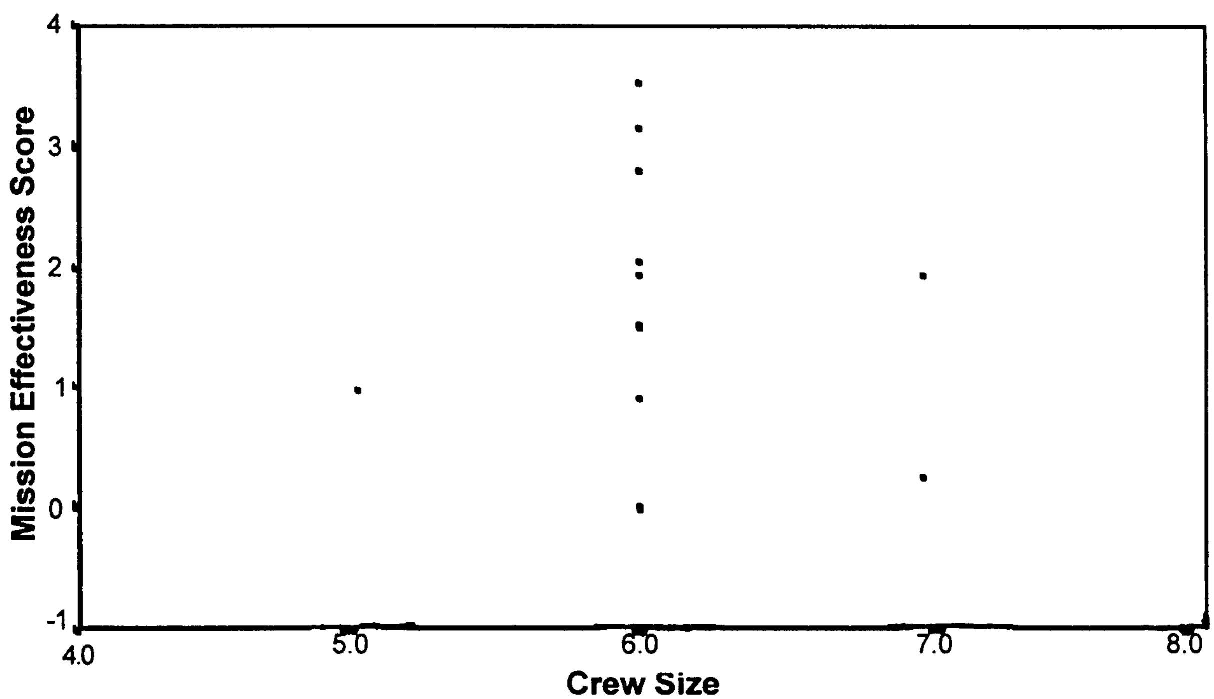

Figure 15. The Relationship between Crew Size and Mission Effectiveness.

Figure 16 is a reproduction of the SME-researcher's process depiction of one of the most effective crews, #7, with the arrows indicating some of the predominant communication patterns among its crewmembers. The other two hub-and-spoke crews (#12, 13) also exhibited this same basic structure, although they had different patterns of observed interactions (i.e., arrows). The SME described such hub-and-spoke crews as having a leader (usually the AC) who "weaves all crewmembers into a cohesive unit."

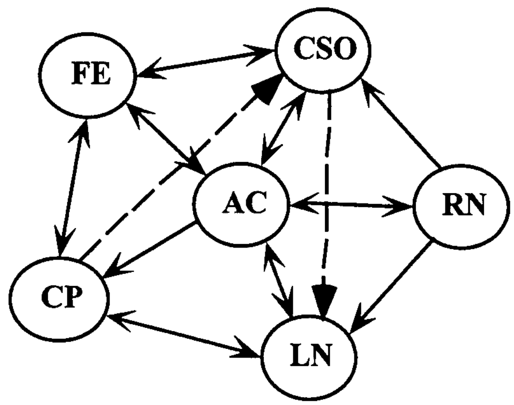

Figure 16. Hub-and-Spoke Crew Structure, Crew #7.

Figure 17 depicts the evolving structure of a crew that "came together" during MP. The graphic depicts a snapshot of the crew structure at 30-minute intervals during planning. As can be seen, the initial stages of planning are characterized by crewmembers working separately (or in pairs). Over time, though, more cohesive groupings were developed based on planning requirements and task assignments. By the final stages of planning, all of the crewmembers were working together with the exception of the FE. The latter had completed his (limited) duties required for the mission and was then tasked to do other things prior to the mission briefing.

Miscellaneous Background Variables. In the absence of any theoretical expectations, we collected and examined the effect of a number of miscellaneous crew background variables from the CBS. These included: average total hours of crew flying experience, average total MC-130P flying hours, average number-of-hours experience in the real-world AO of the simulated mission, number of crewmembers with experience in the AO of the simulated mission, and number of CRM training hours of the crew. None of these background variables showed any systematic relationship (linear or otherwise) to mission effectiveness. Perhaps most notable in this list of background variables was CRM training experience. We examined average number of prior CRM training hours the crew had received, minimum number of CRM training hours within the crew, and maximum number of training hours within the crew. In each case, CRM appeared to exhibit no relationship to crew mission effectiveness. The absence of any relationship to CRM training is obviously disappointing and is a finding that will be scrutinized in future work.

Behavioral Characteristics of Effective Crews

Besides the large number of quantitative ratings that were generated, we also recorded extensive and detailed observations of T^2RM process and performance-related behaviors for each of the 11 crews. Below, we describe some behaviors that seem to characterize the three most effective crews depicted in Figure 13 (#7, 12, and 13). We hope to expand upon this preliminary analysis in a future report on T^2RM.

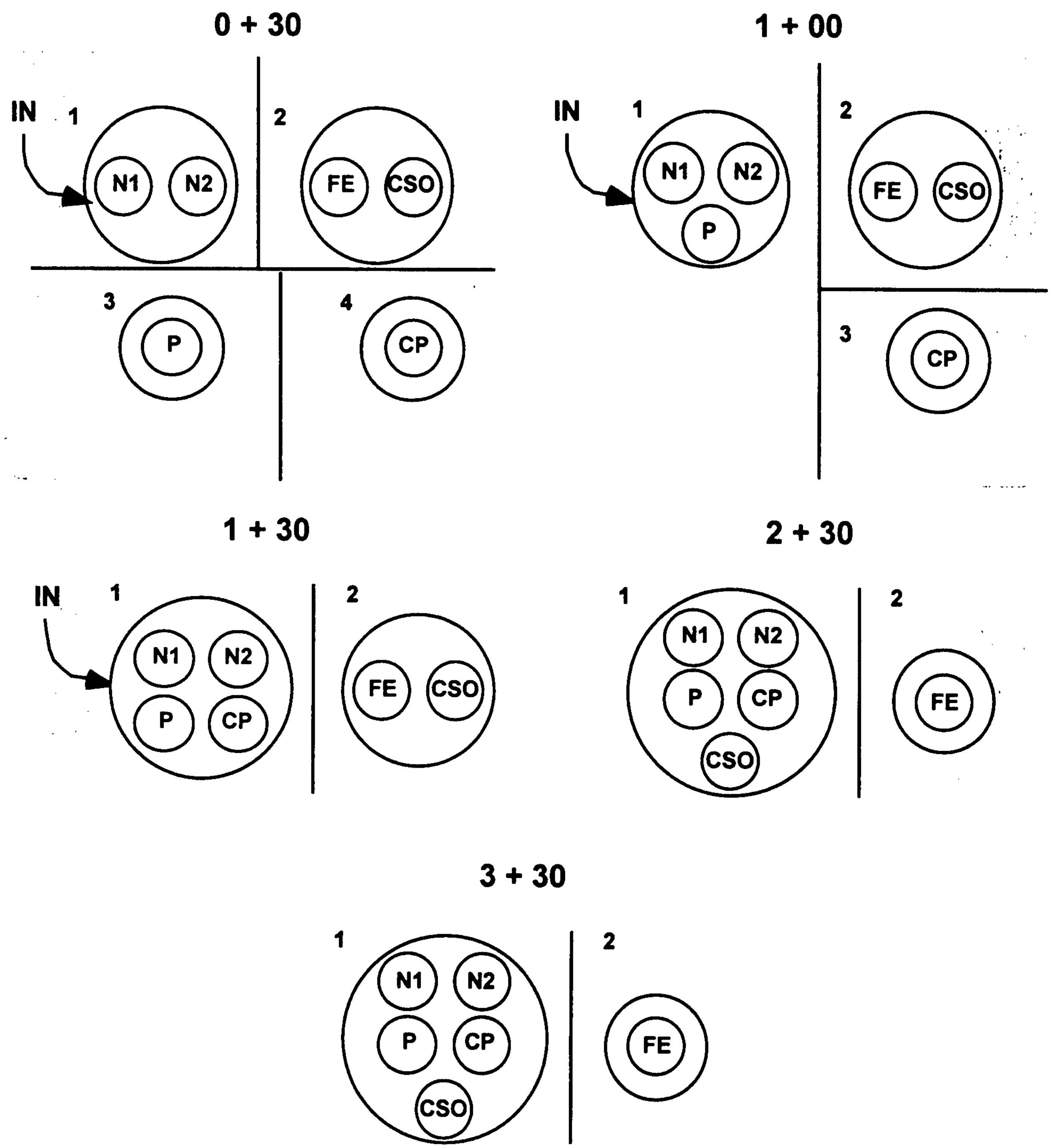

Figure 17. Evolving Structure of a "Crew that Came Together," Crew #2.

Recall that high SA ratings were often associated with good mission performance. Some of the SA behaviors from the T-MOT that accompanied the high ratings were:

1. More consideration of the "big picture;"

2. viewing the crew as only a part of the (larger) team and mission;

3. extensive "what-iffiing," especially of main mission events, including input from the entire crew;

4. willingness of the crew to change their plan even if it caused some confusion to the crew, based on the evolving mission and changing situation;

5. including explicit contingency plans within the pre-mission briefings, e.g., no waiting on the AR track if the helicopter is late or cut the jumper if he gets hung; and

6. responding well to their own errors or changing conditions.

FA was also highly correlated with mission performance, with two key FA behaviors associated with exceptional crew mission performance. First, at least one crewmember <u>overtly</u> and <u>explicitly</u> designated the duties to the rest of the crew--this was done more than once during the course of the mission. This explicitness was in contrast to the more implicit designation of duties that occurred in the lower rated crews.

Second, the exceptional crews seemed to designate duties based on crewmember strengths rather than position. For example, one AC said, "CP, you'll be in charge of SOFPARS (SOF Planning and Rehearsal System) since you know it." The AC recognized the efficiency of this designation rather than simply assuming since it was a navigator's duty, it should therefore be best completed by a navigator. Another example was an AC who designated <u>all</u> communication responsibilities to the CSO. Although communication is the CSO's primary function, many crews opted for the navigator and/or CP to support these duties as well. This particular AC seemed to realize the complexity of the mission and the necessity to allocate this function solely to the CSO, so that the navigators and CP could focus their attentions on other mission taskings.

In addition, two central TE behaviors were indicative of exceptional crews. One, the "effective" crew responses to threats included more than just avoidance, evasion, and survival. For example, Crew #13 included a separate threat briefing among their pre-mission briefs. This briefing contained a detailed overview of the threat situation (especially "the shooters"), and included preplanned crew responses to the threats depending on threat <u>mode</u> (i.e., search, acquisition, locked). While some weaker crews did not even include a threat briefing in their premission briefings, other weak crews did. However, the latter crews did not include variations in threat response based on specific threat modes as did Crew #13. Two, the highest rated crews had more extensive tactical knowledge than the lesser rated crews. Examples include knowing the typical threats in the AO as well as understanding field (vs. textbook) techniques for threat evasion.

Another superior example of TE comes from Crew #12. Their responses to threats included: (a) asking if anyone on the crew had a visual; (b) asking about aircraft damage; (c) marking the latitude and longitude (lat/long) of the threat encounter; (d) transferring the lat/long information to ABCCC; and (e) suggesting additional countermeasures even after successfully avoiding the threat (e.g., dispatching an F-16 to destroy target " 'X" to ensure the safety of future missions or in the event they were forced back into its vicinity later in the mission).

TM is a fundamental feature of SOF MC-130P missions and was highly correlated with mission performance. The primary behavior that characterized effective crews in this regard was their <u>overt</u> time awareness and monitoring throughout MP and execution. Exceptional crews would set times for briefings and TOTs as well as ask about their progress towards these times. Within weaker crews, monitoring of time status was less apparent and overt, especially during planning. As a result, many weaker crews began briefings late or rushed through their briefings.

Although C3 was not significantly correlated with overall mission performance, there were still C3 behaviors that clearly characterized the exceptional crews.

One, exceptional crews seemed to have a much greater awareness of higher echelon mission players, a characteristic that is certainly related to SA. These crews planned and functioned more as a larger team, including making requests for additional resources to enable successful completion of the mission. In effect, they were much more "out of box" than were the weaker crews.

Two, exceptional crews seemed very conscious of how their actions affected other team players. For example, Crew #12 talked extensively about countermeasures they would use on the AR track and consulted often with the (role-played) helicopter-representative as to what he would use. This inquiry is critical because the AC and CP of Crew #12 did not want to blind the helicopter whose crew was on NVGs by dispensing flares. This crew also did not decide to use the ramp or the door for the AD based only on their time constraints and mission requirements. They consulted with the (role-played) PJs to determine what their needs were. Every other crew simply made the offloading decision based on their own constraints, without any consideration of the PJ's needs. Another effective crew, #13, was also acutely conscious that their actions needed to be coordinated with other team players. For example, the offload of the General was planned with extensive input from the (role-played) General. The crew's AC asked the General where on the runway he would like to be offloaded, the size of the reception party, the validation signals of the reception party, what to do if there were hostile forces in the area, and so on.

A few other process behaviors distinguished exceptional crews from weaker crews. However, these did not readily fall into any of our five T^2RM subprocesses. The most salient "other" behaviors are listed below.

1. Exceptional crews were extremely focused on the mission with little (if any) socialization during planning; there was <u>no</u> chatter at all on the intercom during mission execution.

2. Exceptional crews tended to use extremely aggressive plans.

3. Exceptional crews were characterized as highly integrated crews versus fragmented dyads and triads (as previously described).

4. Exceptional crews had ACs who worked to weave [the] crews together in all mission aspects.

Our T-MPT-based performance observations were not as extensive as our T^2RM observations. Nevertheless, there were still several performance behaviors that differentiated exceptional crews from weaker ones. These behaviors included:

1. High quality and level of detail of pre-mission briefs,

2. high number and quality of mission products,

3. superb mission plans,

4. outstanding time control, and

5. outstanding accuracy for accomplishing main mission events (e.g. drop on target).

In a future report, we will detail more precisely both the process and performance behaviors associated with exceptional crews. We will also begin to explore further the behaviors associated with specific crew positions that hinder and help performance (Silverman, Spiker, Tourville, & Nullmeyer, in press). We strongly believe that a systematic delineation of these discriminating behaviors will have a potentially important impact on T^2RM, and hopefully should be ones that could be incorporated into an ongoing training program.

Supplemental Analyses

We also explored the T^2RM process-performance relationship using the overall performance assessments from the instructors (i.e., from the IRIs) and crewmember self-assessments of crew coordination and performance (from the TMAQ2s). Instructor ratings of crew performance were only minimally correlated with process ratings ($r = .30$), and interestingly, were not at all correlated with the mission performance sums described above ($r = -.05$). Although these low correlations are immediately disconcerting, a closer look at the instructor ratings revealed that the instructors were extremely unlikely to use the entire scale provided. Averaged across instructors, the ratings ranged only from 3.67 to 4.75. Indeed, often times, the comments instructors provided on the IRIs defied their own ratings, with negative observations and assessments associated with average or superior ratings. Because of the restricted scale range and the observed disparity between instructor ratings and comments, we do not view the low correlation between the IRI performance ratings and T-MOT process ratings as particularly damaging to our primary hypothesis.

Recall that the TMAQ2s contained crewmember self-ratings of crew coordination and mission performance. As with our primary instruments, a strong positive correlation was found, $r = .86$ ($t = 6.025$, $df = 9$, $p < .05$, two-tailed). Admittedly, these two sources of data are not independent, as both ratings came from the same crewmembers. Thus, it means that crewmembers who felt their crew did well on the mission were also sure that their crew coordination was good. Nevertheless, this finding provides secondary validation concerning the strength of the relationship between T^2RM and combat mission performance as perceived by the crews themselves.

General Training Observations

Before shifting to the conclusions section, we offer a number of general observations regarding MC-130P ART in this final subsection. These observations are not based on the T-MOT or T-MPT, but come from our experiences attending multiple days of ART, reviewing ART course materials (e.g., AFSOCR 51-130), and holding discussions with ART instructors and students. The observations primarily pertain to the conduct of ART and are categorized into five primary topics: ART curriculum strategy, training objectives, CRM training and delivery, mission planning, and debriefing procedures.

ART Curriculum Strategy

During the course of our data collection, we observed a major change in the MC-130P ART because a multiship simulation capability became operational at the 58 TRSS. On Day 4 of training, MC-130P crews would typically perform systems and procedures (see Table 2) in the WST, which included extensive malfunction practice for the pilots and FEs. However, about halfway into our study, this shifted to accommodate the multiship simulator mission which incorporated MH-53J and MH-60G helicopter teams. The Day 4 multiship mission was similar in many ways to the Day 5 mission, including a limited MP session, an AR, tactical daytime LL, and an I/E. A large proportion of the MC-130P crews and instructors, although enamored with the networking capability, felt that having both the Day 4 and Day 5 mission precluded the opportunity to provide focused training on aircraft systems and EPs.

Training Objectives

MC-130P ART course materials presently lack reference to any CRM training objectives and guidance regarding the manner or matter of skills training to be employed. AFSOCR 51-130 provides only an events-based requirement for ART; no specification for a skills-based training curriculum or course content is suggested. A blueprint is provided for *who* (which crewmembers) should attend ART, what training events and how many of these events should be signed off on an annual basis by completing ART, and the (minimum) number of hours to be logged in the simulator. There is a definite lack of specific, criterion-referenced training requirements, and we observed a great deal of latitude in the execution of ART for some of the academic and simulator periods.

To illustrate, currently AFSOCR 51-130 requires students to perform (on an annual basis) an AR rendezvous and join-up in the simulator. There is also a specification to perform tactical low-level operations in the simulator. The main intent of these requirements, however, is to simply provide opportunities to perform certain training requirements so that these may be "logged off." The squadron does not need to generate local flying sorties to meet these same requirements. Again, AFSOCR 51-130 provides no guidance on how, or at what level of competency, these requirements should be met. Instead, the manner of training is left to the simulator instructors who must work to combine the greatest number of events into a limited number of simulator training hours in order to provide the maximum opportunity to sign off a large number of training events.

Despite these problems, the overall level of instruction was outstanding. However, perhaps due to lack of specific training objectives, several observations regarding MC-130P simulator instructors are noteworthy.

A key observation regarding instructors was variability, not just in terms of style which will always be there, but also in terms of the training they provided. This was particularly evident with threat management and inputting unplanned threats into the scenario. We observed several instructors insert unplanned threats into the scenario, while others did not modify the threat laydown at all. Inserting unplanned threats has a dramatic effect on the scenario's level of difficulty and most crews responded favorably to added threat exposure. One instructor technique that seemed particularly beneficial was the use of additional unplanned threats toward the end of the scenario after the primary mission execution phases (LL, AD, AR, and I/E) had been completed. The scenario in its entirety is too long for the amount of simulator time allotted and instructors generally provide system malfunctions toward the end of the time available to force the aircrew to make real-world, mission-ending decisions. Other instructors simply stop the mission wherever it happens to be after four hours have elapsed. However, one instructor kept inserting more and more threats for the crew to respond to which forced a mission-ending decision, but also provided the crew with invaluable threat exposure. This crew was extremely enthusiastic about the additional threat training they received.

There were also variations in terms of the amount of instructor responsiveness to the needs of the crew and the dynamics of particular crews. One outstanding instructor with extensive past CRM training experience observed the entire MP of an aircrew. He also had previous experience with the two pilots who were present. One of the pilots was a long-time CP who apparently was reluctant to upgrade to AC, despite his capability and skill level. After the MP session was over, the IP retained the other instructors momentarily to inform them of a change in the scenario he was going to introduce for this crew. Towards the end of the mission, he was planning to simulate the incapacitation of the AC, and the CP was going to have to take control of the aircraft and crew. He explained that this would give the CP the practice he needed to boost his confidence, and it would be a unique CRM exercise for the rest of the crew. This kind of responsiveness was also observed intermittently at a crewmember level. For example, instructor CSOs provided more distracter messages to more highly skilled CSOs. At both the crewmember and crew level, this sort of training specificity seemed highly effective.

Finally, interviews with instructors provided important insights into local, environmental constraints that dictate much of the training they can provide. Instructors have noted that they are not empowered to give the type of feedback and critique of ART students they feel is needed. Also, as described above, the local training emphasis (especially for ART) is simply to accomplish a certain number of events (vs training and evaluation) before aircrews return to their squadrons. The number of events logged off during ART is a way for operational squadrons to determine the "value" of ART. None of the instructors endorsed this view, but instead, felt unduly constrained by the demand to accomplish a large number of training events.

CRM Training and Delivery

In terms of the CRM training provided during ART, three general observations stand out. One, the materials covered were somewhat repetitive with those covered during Mission Qualification (MQ) training. Instructors present essentially an abridged version of the two-day MQ CRM course. To add diversity to the material, instructors try to facilitate a more open discussion forum related to the issues presented. This involves students relaying their field experiences of successes or failures associated with the different CRM principles. In theory, this seems to be a good technique. However, our observations revealed that crewmembers are very reluctant to share stories in the current ART CRM training environment, resulting in a very "dry" presentation of materials already viewed (at least) once by ART students. Instructors suggested that CRM lecture/discussion sections of ART have become too large to promote open discussions. That is, the CRM lecture/discussion portion of ART can include as many as six different crews from four different airframes, meaning up to 40 students being trained at once. It is an atmosphere that does not seem to promote self or crew disclosure about mistakes they have made. Instructors have commented about their frustration with the situation and their feeling of the limited utility of simply re-presenting material from MQ without an open forum. With classes so large, instructors do not feel that they have much of a choice. Anecdotally, instructors have commented on the composition of the class as well, indicating that the CRM issues a helicopter crew deals with may be different than those of a fixed-wing operator, especially at higher qualification levels.

Two, there is a striking discontinuity between the content of the two-hour, crew coordination lecture and the training received during the rest of ART. In the lecture, CRM was described as a set of abstract processes (e.g., advocacy, SA, communication) whose relevance to training events in the simulator was not made explicit.

Finally, there was not much feedback provided by instructors to crews on their crew coordination. Not only were the CRM principles <u>not</u> reintroduced during the subsequent days of ART, very little reinforcement (or punishment) was provided to aircrews on CRM behaviors exhibited during the Day 5 "MOST (Mission-Oriented Simulator Training) mission." The feedback that was observed rarely went beyond statements like, "your crew coordination was good." Casual discussions with instructors suggest that this is also a problem for MQ CRM training. They cite the AFSOCR 51-130 which indicates that the goal of CRM training for MQ is "familiarization." However, it is unclear what this entails. Is it familiarization with the terms and principles or the practices of CRM?

Mission Planning

Several observations were made regarding MP training and content during ART. As we have stressed, MP skills are critical components of individual crewmember combat capability and eventual mission success. ART is an ideal arena to practice and hone planning skills, as well as to try out new mission planning tools (e.g., SOFPARS), especially on Day 5 of ART where a full-mission team complement and a real-world mission are used.

MC-130P ART provides crews with four hours of planning time for Day 5's mission, access to state-of-the-art tools like SOFPARS, several sources of information on the latest threat capabilities, access to copiers and real-world planning products and tools, and instructors for each crew position. Nevertheless, we observed several deviations from this ideal. If there were unforeseen time constraints or scheduling conflicts, MP usually suffered the most. For example, although instructors were always present for the entire mission execution phase, they were often given concurrent duties that conflicted with the MP phase of training. This hindered their ability to provide feedback to the crew or individual crewmembers for this critical mission phase. Also, ART scheduling difficulties were noted three times during the study, and each time the MP stage was the only stage of the mission that was affected. On two of these occasions, the MP time was reduced by an hour and once it was cut in half. Aside from markedly reducing the effectiveness of MP training, these cuts send a potentially devastating message to aircrews about the lack of importance of MP to overall mission success. Additionally, and perhaps related to the newness of SOFPARS, this tool was only available to about half the crews that we observed. The variable that seemed to dictate availability of SOFPARS to aircrews was instructor familiarity with its use. Finally, and perhaps inevitably, there were several complaints by aircrews that the tools they normally (i.e., in the field) use for MP (e.g., Integrated Many on Many System or IMOMS) were not available, which they felt made the MP process somewhat artificial.

Despite SOF crewmember schedules and the temptation to coast through an easy week of training, we observed crews who were highly motivated and wanted to achieve the maximum training value for time they spent at KAFB. However, there were some exceptions, mostly by individual crewmembers. However, there was one crew that seemed to feel that MP was not an essential component of their week of ART. This crew basically "blew off" MP and performed worse than other crews during the mission execution stage. In contrast, other crews worked vigorously on the MP tasks, with two crews even working through lunch to prepare for the mission.

Debriefing Procedures

There is nearly universal agreement among MC-130P aircrews about the value of debriefs for training and crew coordination (Spiker et al., in press). However, mission debriefs rarely went beyond critiques of flight procedures and filling out end-of-course paperwork. Debriefing procedures and topics were strikingly inadequate. For example, although there is a detailed script of events and procedures for the mission execution stage, the topics and requirements of the debrief are loosely organized. Many instructors wrote down particular events and exchanges from the

mission to discuss during the debrief, but even those were often given short consideration as time had a tendency to run out. Also, videotaping have been cited as an invaluable CRM training medium (e.g., Diehl, 1995). Although the capability exists within the MC-130P WST, we never observed its use. The MC-130P WST also has various crew performance pages that can be printed out and used to aid instructor debriefs. Over the entire course of our study (including baseline observations), we only observed one instructor use this medium. Notably, the crew/pilot who received a debrief using this tool was visibly excited about the documentation, and after declassifying the printout, took it with him.

Finally, MC-130P ART suffers like many areas of the USAF in terms of the pressures on the personnel. The instructors have numerous responsibilities, only one of which is ART. As we have already mentioned, ART instructors were often "double booked" and unable to attend certain portions of training. This potentially reduces their ability to guide students and provide observations and feedback.

CONCLUSIONS

We conclude this report with a series of discussions concerning future directions for CRM-related training, research, and implementation. We begin by summarizing the major results of the study, with primary emphasis on areas where prior research either was or was not replicated. Next, we discuss some of the directions that future CRM research should take given the present results. Then we describe the implications of this research for future USAF R&D, particularly as it pertains to joint service training and distributed mission training (DMT). Finally, we discuss the implications of our findings for improving the delivery of CMT, both at the 58 TRSS and beyond.

Summary of Major Findings

The most salient finding of this research was the replication of the Povenmire et al. (1989) observation that crew coordination process is a significant predictor of tactical mission performance. In our study, this relationship was supported by a correlation of .86 (or .89 if independent process and performance rank orders were compared). There has been limited support for this finding in previous empirical investigations (e.g., Thornton et al., 1992). There have also been numerous descriptions of the relationship between crew coordination and performance in the context of accident investigations and safety violations (e.g., Diehl, 1989; Predmore, 1991; or Taggart, 1993). However, direct empirical support for this relationship has been scarce, especially in tactical environments.

The significant correlation between T^2RM process and mission performance then afforded us the opportunity to explore the relationships of particular subprocesses, mission phases, and ultimately, specific behaviors to overall performance and T^2RM. These detailed analyses provide us with the critical information required to: (a) offer feedback for the CRM-CMT training curricula, (b) improve our data collection instruments (e.g., by making them shorter, more efficient, and portable), and (c) further our research efforts.

Some of the highlights of the detailed analyses of the process-performance relationship are summarized below. For each main finding, we try to establish how it fits in to past CRM research. In addition, we offer potential explanations for some of the findings based on our knowledge of the MC-130P SOF mission, interviews with SMEs, and skill levels of ART attendees.

T^2RM process in the MP, AD, AR, and I/E mission phases were all highly correlated with total mission performance.

This result provides empirical confirmation that crew coordination--T^2RM process--is critical to performance *throughout* the entire mission. Past CRM training evaluation research has focused on student attitudes, learning motivations, and crew behaviors during, immediately following, or any time after the training occurred (Gregorich & Wilhelm, 1993). Many of those who have focused on CRM evaluation *during* training or MOST missions (like us) have assessed CRM behaviors at several points throughout the entire mission (e.g., Fowlkes, Lane, Salas, Franz, & Oser, 1994; Helmreich, Wilhelm, Kello, Taggart, & Butler, 1990). Fowlkes et al. (1994), used their TARGETs (targeted acceptable responses to generated events or tasks) methodology to assess CRM across three segments of a military helicopter cargo mission. They found distinctions in "CRM performance" across the segments, noting CRM-performance advantages for those crews that had ACT versus those that did not. Similarly, the Line/LOS (Line Operation Simulation) Checklist (Helmreich et al., 1990) is designed to assess CRM across four mission phases (predeparture, take-off and climb, cruise, and descent/approach landing). Clearly, past researchers recognized the importance of CRM assessment for the entire range of mission phases. But until now, there has been a surprising lack of data that ties phase-specific CRM evaluation to mission performance.

MP and LL performance showed the highest association with overall T^2RM quality.

We found performance in the MP and LL phases to have the strongest association with crew T^2RM. This is, we believe, due to the relatively long durations of these mission phases compared to the other phases (AD, AR, and I/E). MP behaviors are sampled over the course of the entire 3-hour planning session, in the form of evaluations of prepared charts, flight plans, number of briefs, quality of briefs, etc. Similarly, LL performance is assessed at various intervals throughout the entire mission. As such, MP and LL perhaps offer the most stable measures of crew performance.

Both MP process and MP performance had a large impact on total mission performance.

The importance of MP for the successful execution of military aircraft missions is a cornerstone of AF doctrine and training (Hunt, 1993). While it stands to reason that more effective MP should result in better mission performance, until now, there has been little empirical evidence to support this assumption. Studies of team mission performance have typically not included the MP period as part of the measurement process. This is perhaps because MP involves a host of cognitive processes which are inherently more difficult to measure than mission performance (Taylor, 1993). Some investigators, on the other hand, have inferred the type of MP processes

that must have occurred and anecdotally linked those to mission performance (e.g., Thornton et al., 1992). Our study provides empirical evidence that more effective MP is associated with better mission performance. The relevant correlations ranged from .60 to .78. The SME's rating of crew coordination *process* during MP was related to the second researcher's rating of overall crew mission performance during MP. Additionally, ratings of the *products* generated during MP were a significant predictor of crew performance during the four mission execution phases.

SA, TE, FA, and TM were all significantly correlated with total mission performance, while C3 was not.

Perhaps due to our rather extensive pilot work, including interviews with SMEs and a review of recent CRM literature (see Spiker et al., 1996 for details), all but one of our selected T^2RM subprocesses correlated with mission performance. Where possible, we selected subprocesses that made contact with past CRM and pilot/crew performance research (e.g., SA and C3), while providing as much of a tactical focus as possible (e.g., TE).

SA. In the last decade, there has been a veritable explosion of research on SA measurement (e.g., Bell & Waag, 1995; Endsley, 1995a), definition (e.g., Endsley, 1995b; Flach, 1995), and use (e.g., Carretta, Perry, & Ree, 1996; Endsley, 1995b). However, there have been some ambiguities in distinguishing SA from performance, and accordingly, whether it is simply a phenomenon to be described or it is a truly causal entity (Flach, 1995). In addition, the focus of previous SA research has been in the area of individual versus team SA (Salas, Prince, Baker, & Shrestha, 1995). In the present study, we focused on team SA as a process that is measured separately from performance. In this manner, we established all of our T^2RM subprocesses as potential causal antecedents to mission performance. Important SA behaviors include: confirming and cross-checking information within the team, communicating relevant information to crewmembers, integrating information, etc. Our results then tie team SA to mission performance and, as we detailed previously, also provide concrete and reinforceable SA behaviors.

FA. Past research has also blurred the distinction between workload and SA (e.g., Hendy, 1996). In our study, we assess a related concept, FA, where the consequences of poor FA are either work overload or work underload for specific crewmembers. We found that FA behaviors involving clear and overt stating of crewmembers' roles and responsibilities were highly correlated with overall mission performance.

TM. In our study, crews who stated, monitored, and "stuck to" planned times performed better than those crews who did not. The SOF mission used in our research was very demanding and event-filled, imposing severe time pressures on all participants. In fact, many crewmembers commented that, in the real world, they would plan for such a mission over 2-3 days rather than the 3-4 hours provided—conditions that could easily lead to a need for good TM.

Moray, Dessouky, Kijowski, and Adapathya's (1991) application of scheduling theory to the optimization of a simple human performance task perhaps offers some descriptive value here. Scheduling theory is primarily used in industrial engineering to address problems of timing and sequencing of operations. The questions that scheduling theory address in a machine

environment are similar to those a SOF mission team must address: In what order should tasks be tackled? Which (if any) task should be interrupted, and when? How long will the completion of all tasks take? Will there be any spare time between tasks, and how should it be used?

Like the Moray et al. (1991) research, the SOF mission teams we observed had several tasks to perform (e.g., AR, AD, prepare charts, etc.). The teams were free to choose the order and timing of tasks that were performed for MP and much of the timing of events during mission execution. Scheduling theory assumes that despite all these choices and tasks, explicit application of appropriate rules and selection criteria (e.g., number of tasks to be completed or timelines) will lead to optimal performance and reduce subjective workload. Thus, those crews who defined crewmember roles and responsibilities (FA) and explicitly stated their timelines of performance (TM) were implicitly applying scheduling rules and selection criteria to be met. This could, in turn, explain their superior performance compared to other crews who did not provide this explicit rule-based direction to help guide their collective actions.

TE. The truly unique area we applied to CRM was TE. Although one can logically assume that an individual's threat knowledge and understanding will aid performance in a hostile environment, there has been virtually no work done on distribution of tactical knowledge among a team and the team's application of that knowledge. This is the essence of our TE subprocess. We found that better TE was associated with better mission performance, where we focused on issues like: crewmember exchange of threat information, threat response in the context of other mission players, and discussion of various tactical choices.

C3. Within the context of other CRM research, perhaps our most interesting finding was that C3 was *not* correlated with mission performance. A host of CRM researchers have used communication as their primary index of crew coordination (e.g., Kanki, Lozito, & Foushee, 1989; Krumm & Farina, 1962; Lassiter, Vaughn, Smaltz, Morgan, & Salas, 1990). Interestingly, most of these studies found various communication correlates with their performance measures. For example, Kanki et al. (1989) found that homogeneity of speech patterns (use of more standardized and predictable speech) was characteristic of crews with fewer performance errors. Accordingly, Lassiter et al. (1990) rated two-person helicopter teams on their communication and mission performance and found a significant positive correlation.

There are several potential reasons for our null result in terms of the link between communication and mission performance. One, we took an extremely tactical view of C3, defining it to include the crew's use of, and communications with, external team members (e.g., coordinating action items with ground parties) as well as the crew itself. As such, our C3 units of measurement were not at the level of detail (e.g., transcribed "thought units") of much of the past work on communication and performance. The fact that our C3 focus included outside parties may have also lessened sensitivity of the measure due to current operating constraints as well as the use of a single simulator. That is, a key operational component of C3 for most SOF mission teams involves coordinating mission events with other mission players, which our C3 measurement indices were designed to assess. These outside agencies and players were typically role-played by instructors or our P/O which admittedly has a certain artificiality. Thus, our

measure of C3 may be a more powerful predictor of performance in the context of a multiship simulator mission (e.g., DMT) where other players are actually present.

Another potential reason for the lack of a C3-performance relationship is that at the ART level of training, communication skills and procedures have already been ingrained in SOF aircrews and, as a result, there is limited variability within this T^{2}RM subprocess. Supporting evidence for this notion comes from research done on the Crewmember Management Attitudes Questionnaire (CMAQ) (Merrit, 1996). In a cross-cultural analysis of individual CMAQ items, she found that those items relating to communications were "universally, negatively skewed, suggesting strong pilot endorsement of the concept" (p.97). As such, the communication items have limited diagnosticity between crews or crewmembers.

In addition, several post hoc, SME interviews suggested that operating requirements that are instilled in MC-130P SOF aircrews demand that crew communication within and without the cockpit be held to an absolute minimum. One interviewee put it quite succinctly when he said, "shut up and be there--that is our tactic." He further explained that the goal of an MC-130P cockpit is to be quiet and efficient during combat missions. In fact, one of the items that must be completed on the MC-130P, low-level checklist is to turn off the wafer switch to ensure that no external transmissions occur. Other SMEs concurred, stating that during tactical missions one does not want too much communication in the cockpit because this will potentially distract crewmembers from the threats. These descriptions of the MC-130P environment explain the low correlation between C3 process ratings and crew tactical mission performance. Further endorsement of these descriptions was found when we looked at the variance of the rated subprocesses (SA = 13.04, TE = 10.83, TM = 9.65, C3 = 7.89, and FA = 5.78). C3's relatively low value indicates perhaps that there was not much for our researcher/observer to rate, as most of the crews were following typical "comm out," MC-130P procedures.

We stress this divergence from the literature on CRM to illustrate the importance of specific tactical or even weapon system-specific CRM training as opposed to general CRM training. That is, this finding is atypical of the work in commercial aviation which shows the relationship of communications to performance (e.g., Predmore, 1991). It is one factor (of perhaps many) that clearly distinguishes a tactical environment from commercial aviation environments. It may be a subprocess that will also have varying relevance across airframes. One SME pointed out, for example, that the MH-53J may require more communication and coordination due to the nature and requirements of their mission as opposed to the MC-130P.

Phase-specific performance and phase-specific T^{2}RM indices were positively correlated, but none were significant.

Although none of the phase-specific, process-performance relationships were statistically significant, they all trended positive and provide additional evidence of the strong relationship between crew coordination and mission performance. One potential reason for the decreased process-performance correlations is that ratings by mission phase are bracketed in time where raters based their assessments on smaller samples of crew behaviors. As such, mission phase ratings may not be as stable as overall ratings.

The individual T^2RM subprocesses had differential impact on mission performance across the phases.

The differential impact of T^2RM subprocesses on phase-specific mission performance has important implications for CRM training developers and instructors. Specifically, optimal crew coordination training would highlight different subprocesses depending on the mission, phase, and key training events. Below, we offer brief explanations for the patterns of subprocess correlations with performance in each of the five mission phases (Table 10).

MP. SA had the highest correlation with MP performance, closely followed by TM. This result is not surprising if one considers the tasks of MP (reading the FRAG, detailed map study, calculations of route and leg times, route planning, reviews of EW and Intel information, etc.), combined with our definition of SA as an "integration of multiple pieces of information." The associated high correlation with TM suggests that good MP will result when information is integrated in a timely and efficient manner.

Also notable was the low correlation between FA and MP performance. It is striking because of the number of tasks (e.g., charts, briefs, flight plans, E&E plan, etc.) that must be completed during the compressed MP time period for this mission. It might be logically assumed that crews who distribute the duties and resources effectively and efficiently would have superior MP performance. The relatively low correlation between FA and MP performance ($r = .22$), however, indicates that this is not necessarily so. SME interviews shed light on this seemingly perplexing result. An operational MC-130P pilot smiled and said, "This is typical of this community; we just let the navs plan."

LL. FA had the highest correlation with LL performance. Although delimiting crew roles and responsibilities (FA) seem to be highly correlated with all mission execution phases (see Table 10), its relative impact was the highest for LL. It is perhaps the duration and diversity of the activities that occur during LL which make FA so critical. For the other mission phases (excluding MP), the focus was on a specific mission event (an AD, an AR, or an I/E). However, there are multiple mission events during LL, and tasks must be performed simultaneously and continuously (vs. discretely). Therefore, it may be more critical to clearly delineate crewmember functions to better perform during LL.

Somewhat surprising in terms of the subprocess rating correlations with this mission phase was the extremely low correlation between TE and LL performance ($r = .06$). SMEs pointed out two potential reasons for this. One, they suggested that artificiality of the simulator environment may be driving TE behavior more than the other subprocesses. That is, crews know that the scenario will run for the scheduled mission and that they will not necessarily suffer any of the consequences (e.g., death or mission termination) of poor threat tactics. Two, SMEs cited the fact that in the real world, MC-130P crews do not routinely fly penetrating, low-level missions in a threat environment, and as such, TE should not be expected to be a discriminating factor.

AD. TM had the highest correlation with AD performance, closely followed by SA. One of the most critical performance requirements for an AD is hitting the target at the planned drop time. Crews that were best at achieving this performance requirement were those who called the drop warnings, and called and executed the associated checklists in a timely fashion. In addition, SMEs suggested that SA's relative impact on AD performance was understandable given the demands of the AD. They noted the high workload demands of an AD posed by running several checklists and reconfiguring the aircraft. They also noted the importance of integrating multiple crew perspectives and information as the crew works to identify the DZ. All of these factors require high crew SA to enable superior performance.

AR. For reasons not immediately obvious, TE had the highest correlation with AR performance. In fact, TE-AR was the only correlation among the 25 subprocess, phase-specific performance pairings that reached statistical significance after correcting for multiple correlations. AR is one of the primary functions of MC-130P crews, and as a result, the crewmembers who arrive at ART have considerable experience with this mission event. Consequently, many of the AR-specific behaviors that fall under our other T^2RM processes—such as coordination with the helos (C3), timely coordination and execution of checklists (TM), or establishing the FE's duties (FA)—may all be second nature to these crews. The process behaviors that discriminate good ARs from other ARs seem to be those of a tactical nature: recognition of the need to lower the suggested altitude to better avoid potential threats, establishing loitering procedures over water, and discussing threat countermeasures while on the AR track.

I/E. Like MP, I/E requires crews to integrate various information sources (the tower, the reception party, ABCCC reports on the threat situation, the customer, etc.). And like AD, the crew must reconfigure the airplane, run multiple checklists, and incorporate multiple crewmember perspectives. All of this is compounded by having the pilots land while wearing NVGs. Not surprisingly, SA had the highest subprocess correlation with I/E performance, closely followed by FA.

Predominant squadron affiliation, crew orientation, crew structure, and crew size all potentially influence crew mission effectiveness.

We did not explicitly manipulate any of these factors, so we strongly recommend further research to more definitively establish their relationship to crew effectiveness. However, the initial trends appear to support the view that training is an organizational episode (Baldwin & Magjuka, 1997). The primary thrust of this view is that there are various factors outside of the delivery of training itself that will affect the efficacy of the training and the performance of the group, or in this case, the crew. Three influential pretraining factors are: the introduction of training, the social cohort, and the transfer climate. Of particular importance to the above findings is the influence of social cohort. Baldwin and Magjuka (1997) note that just bringing trainees together does not necessarily yield effective training. Group composition factors such as individual backgrounds, group size, and crew orientation will all affect the group training effectiveness. Though our sample size precluded statistical testing, we have preliminary evidence for comparable effects with aircrew performance.

Past CRM training hours were <u>not</u> related to crew mission effectiveness.

Conclusions based on a null result are tenuous at best, but this one merits reiteration—a crew's past CRM training experience (as defined by number of CRM training hours) was not related to mission effectiveness. There are several possible reasons for the lack of a relationship. On the one hand, it is difficult to quantify a *crew's* experience in CRM training, since the metrics to combine individual training hours into a meaningful group index are not yet known. On the other hand, it is more likely that given the tactically demanding events of this CMT scenario, the generic concepts typically covered in USAF CRM courses would offer little unique value, hence a null result is entirely plausible. At least at the ART level, CRM training requires further refinement to include more tactically relevant concepts. This topic will be discussed in the closing subsection.

Concrete behaviors depicting the T^2RM process and mission performance of effective and ineffective crews can be isolated.

Finally, the present study showed convincingly that concrete behaviors depicting the process and performance of effective and ineffective crews can be isolated. There is presently a movement within USAF CRM curriculum development toward emphasizing skills and behaviors versus concepts (Wilson, 1995). By establishing the <u>behaviors</u> that coincide with each T^2RM subprocess, we can help further movement in that direction. As Helmreich and Foushee (1993) succinctly state: "It can be argued that programs that employ concrete behavioral examples should have a greater impact on crew processes and outcomes than those that deal with abstract concepts (p. 27)."

Each of these results has important implications for training, evaluating, and promoting CRM concepts among instructors and students. Some concrete training recommendations based on these central findings are described in the closing subsection.

Implications for CRM Research

The diversity and richness of the empirical data produced by the present research suggest a number of directions for conducting follow-on research. In this subsection, we discuss eight "thrusts" that we believe will have the largest payoff for creating a substantive knowledge base to support future CRM research.

A first thrust entails developing an understanding of the nature of our quasi-experimental methodology and having an appreciation for why it was successful. Specifically, the use of an SME-researcher to collect team process data, following Povenmire et al. (1989), is one of the cornerstones to our T^2RM measurement model. From our experience, one cannot overstate the importance of having a highly experienced researcher serve as one of the observers. For example, Nullmeyer, Bruce, and Spiker (1994) have noted that the complexities of CMT, as with any organizational system, require the use of an SME with an "eye trained for spotting relevant events in what could be an unintelligible thicket to the uninitiated." When armed with a

structured observational protocol, the SME-researcher gives one a more "precise lens" on what otherwise seems like a chaotic week of training, thereby increasing the chances that critical T^2RM behaviors will be captured. This stands in contrast to videotaping, which can be costly and inefficient, and highly objective checklists, which can be used by nonSME-observers but may not capture the tactically relevant behaviors specific to a mission scenario.

Given we accept the importance of an SME-observer, we must identify the key qualifications he/she should possess for use in future research. Based on the present research, it is clear that the SME should have expertise in the tactical domain of interest, experience in training student-crews in the particular weapon system, and an affinity for and appreciation of research. Such individuals are, of course, not easy to find. However, the methodological rewards from obtaining the services of such an individual are certainly worth the search. As an added benefit, materials developed for use by the SME-researcher will be, with only minor modifications, equally well-suited for the CMT instructors. Hence, protocols that help the SME-researcher observe and capture notable T^2RM behaviors can also be used by the CMT instructors to identify and reinforce those same behaviors.

A second methodological thrust concerns the importance of maintaining independent estimates of process and performance data in all future research endeavors. Not only will such independence ensure that one obtains an unbiased estimate of the strength of the relationship between team process and mission performance, it will help to ascertain the more "dynamic" crew-team processes that can potentially be impacted through targeted training interventions. As a follow-up to the present study, we will be reviewing in detail the SME-generated notes from the T-MOT to extract the most notable T^2RM behaviors, positive and negative, which can be cost effectively targeted during CMT.

At an even more basic level, there is a pressing need for additional empirical studies that confirm a significant correlation between team coordination processes and mission performance. These are the correlations that tell us *which* processes are most important, i.e., have the largest impact on performance. In this regard, it is telling that there have been so few published attempts at replicating the basic Povenmire et al. (1989) process-performance correlation in the tactical domain. On the one hand, such replications are difficult since they require on-site observers rather than recording audio communications or videotaping student crews. Training resources are limited, so it is imperative that we have the means to unequivocally identify high payoff processes, and then develop and target interventions to train, reinforce, and sustain them. At a minimum, this will mean that subsequent studies have two researcher/observers, or at the very least, one process-observer and some independent means (e.g., via computer) of recording mission performance. In the context of our T^2RM measurement model (see Figure 1), we have already expressed a belief that performance will need to be handled almost as delicately as process, by means of an observer who has access to the full range of materials created during CMT (annotated charts, ground tracks, etc.).

Third, it will be important to show that the present study's observation of a pronounced relationship between process and performance is not limited to a particular weapon system, mission scenario, or training regime. Indeed, the generalizability of any finding is traditionally

considered to be a logical next step for research. While not always viewed as theoretically exciting, replication of basic phenomena in other contexts is essential to advancement of any research base. Importantly, replication of a study's principal finding is a more convincing form of scientific evidence than is the size of the statistical finding in the original study (Cohen, 1994).

For example, crew complement in the MC-130P WST--six--is rather large. Do team process effects still exist when crew size is reduced by half--to three--as in the MH-53J WST? Does the nature of fixed-wing operations lend itself to larger team process effects than might be found with helicopter operations? Future work is certainly needed to delineate the boundaries of the size of T^{2}RM process effects that one can expect to find in these other contexts. At one level, there is no a priori reason why our present results would be characterized by an unusually large process-performance association. In fact, this relationship might be even stronger when crew size is smaller because each crewmember's role is proportionally more vital. Moreover, one can ask whether a large effect of T^{2}RM process will still be observed when we study less experienced crews, such as the beginning student-crews trained during MQ. From a training standpoint, it is noteworthy that a substantial process-performance relationship was observed with the highly experienced ART crews of the present study, as it implies that, regardless of experience level, there is room for improvement via targeted training.

Fourth, the present results strongly underscore MP as a very promising area for further research. On the one hand, MP is the initial phase of the Day 5 ART mission, so we inevitably see the team process effects first appear. Recall that in our assessments of MP effects on T^{2}RM, we identified three types of crew orientation—mission, task, or training. In the future, we will want to develop targeted interventions to promote constructive team-building behaviors during MP, so that either a mission or task orientation is adopted by *all* crews.

Moreover, with regard to MP, it is clear that we have only begun to "scratch the surface" of this potentially important area. For example, does having access to an automated planning system stifle development of critical T^{2}RM behaviors? Or, does such access give planners more time for information-sharing and assumption-testing activities that are so essential for good preparation (Spiker & Nullmeyer, 1995b)? Similarly, does having access to high fidelity simulation and geospecific imagery overemphasize the technological aspects of MP at the expense of the more personal, T^{2}RM-oriented issues? These and other questions merit study in their own right, particularly as the SOF community moves ever closer to integrating computerized systems into its MP process, both real world and training.

As a fifth thrust, future work should explore the extent to which T^{2}RM and CRM studies represent two distinct research strands. That is, if tactics play a dominant role, does that mean that CRM principles identified from the commercial airlines industry no longer apply? At the present time, we do not know the answer to this question, although the present study provides some preliminary data to consider. Specifically, TE and SA comprise the two subprocesses that are more scenario-dependent than are FA, TM, and C3. From reviewing the content items of the T-MOT, it is clear that both subprocesses are marked by notable behaviors that vary considerably across mission phase. For example, the TE subprocess is represented by such diverse behaviors as use of terrain and altitude (LL), technical proficiency (AR and AD), and coordination of threat

procedures (I/E). On the other hand, a subprocess such as FA is characterized by such stable behaviors as "crew involvement" that change little from phase to phase.

To assess the phase-specific nature of these subprocesses, we computed the overall between-crew variability in T-MOT ratings as well as the between-crew variability within each phase. As expected, overall standard deviations for the ratings were higher for SA (3.61) and TE (3.29) compared to the other three subprocesses (2.40-3.11). In addition, when standard deviations were computed for each phase separately, TE and SA had either the first or second highest standard deviation within each of the five mission phases. Taken as a whole, these analyses suggest that (a) tactical behaviors play a major part of a crew's T^2RM and (b) these behaviors will likely be more variable in their definition and occurrence across missions, weapon systems, scenarios, and crews. Given such likely variability in a major component of T^2RM, it stands to reason that, at least within the CMT domain, CRM courses should be weapon system-specific.

A sixth thrust concerns the need to have future research take a closer look at T^2RM processes associated with teams for which a variety of non-aircrewmembers (e.g., Intel) interact with the aircrew. The CMT environment of the present research effort only partially captured the flow of information in a larger team through the use of role-playing instructors during MP and mission execution. Yet we know that such information exchange plays a major role in the crew's decision making process, and hence is very relevant to T^2RM principles. To gain a broader perspective on "teamness," it is necessary to apply our team measurement methodology to a larger tactical environment in which more individuals play an active role in the mission. Possible environments for supporting a more team-intensive scenario include the Day 4 ART networked training mission, Joint Readiness Training, DIS demonstrations, and joint field exercises.

It is our firm belief that the basic methods of team measurement would still apply in these other environments, although additional T^2RM subprocesses may be identified and operationally defined. As before, a front-end analysis would be needed to identify these new subprocesses and determine how they relate to the existing, crew-based ones. Many other candidates will emerge, but several possibilities for new T^2RM subprocesses include decision making, workload distribution, and "team" awareness (i.e., understanding one's crew role within the larger team objective). Implications for conducting research within this "larger team laboratory" will be further elaborated in the next subsection.

A seventh research thrust would entail exploring the effects of individual crewmember positions on T^2RM processes and behaviors. In this regard, we primarily emphasized T^2RM subprocesses and behaviors at the *crew* level. However, our data collection instruments (e.g., the T-MOT) were designed to also capture T^2RM-related activities at the individual level. In a follow-up to the present study, we are analyzing the existing data set to determine if there are pronounced effects of T^2RM associated w0ith the characteristics and proficiencies of individual crewmembers (Silverman, et al., in press).

While definitive answers to the above questions await further research, we looked at the latter question by computing the correlations between the T-MOT-based T^2RM ratings associated

with each crew position and the crew's overall T^2RM rating. Results showed a wide range of correlations, indicating that a crew's overall T^2RM is *not* simply an arithmetic average of the individual crewmember ratings. Specifically, we observed the following correlations: LN (.89), CP (.86), AC (.79), RN (.64), FE (.41), and CSO (.20). This pattern is quite instructive, as it gives us some insight into crewmember influences on the T^2RM process, at least for the MC-130P weapon system.

The LN's large impact on crew T^2RM is consistent with his/her role as developer of the flight plan during MP and continual guidance he/she provides to the pilots throughout the mission. The high correlation for the CP might be considered surprising, although it is our opinion that it reflects the fact that the more effective crews made better use of the CP's time, particularly during MP, which translated into more effective T^2RM behaviors during the mission. On the other hand, the low correlations for the FE and CSO are consistent with our observations that both crewmembers were underutilized during much of the MP process, and were similarly under-engaged during selected mission phases. It will be interesting to determine whether a comparable pattern of correlations holds up under other mission conditions, and whether other weapon systems exhibit a similar wide range of crewmember T^2RM associations.

An eighth and final thrust involves the identification of critical, stable, and effective crew process-behaviors that will form the core of a T^2RM content domain, regardless of the tactical scenario, mission, or weapon system. At the present time, we do not know what these foundational behaviors are. The five T^2RM subprocesses—and associated T-MOT behaviors—addressed in the present study are only a first attempt at establishing their identity. The detailed analysis of T^2RM behaviors during the MP phase gave us some further insights, but additional research in this area is clearly needed.

To illustrate, in reviewing the T-MOT data from the three most successful crews, the following observations were commonly made. First, the AC provided verbal backups during periods of communication ambiguity and kept the crew informed (as required) on what was happening. The LN integrated inputs from the RN and CP, and helped the AC make decisions. The other crewmembers accepted AC and LN's communication as primary, and theirs as secondary. Moreover, multiple crew positions caught and corrected errors by other crewmembers when they got behind or tired (e.g., the AC and RN catch and correct navigation errors by the LN). The CSO "passed comm" in short bursts of understandable information. As well, the crew always had a backup plan for who would take over a system function (e.g., expendable deployment) when it came out of auto mode. Smooth, crisp communication between the crucial dyads (AC and CP, AC and LN, LN and CP) was evident throughout the mission. Communication filtering between crewmembers was based on perceived workload and timing of the mission event.

Identification of these T^2RM behaviors will clearly arise on an incremental basis, but once specified, they would provide the core content for a T^2RM course that would be taught at the MQ level. To make this determination, we would first look for T^2RM behaviors that appear to transcend tactical mission phases and scenarios. Then, we would more closely examine individual, weapon system-specific T^2RM behaviors to see if we can identify antecedent factors

that tend to promote/reinforce some behaviors as well as punish others. Once these factors have been identified, and psychometrically robust instruments developed to measure their occurrence, we will then have taken a major step forward in our quest to design training interventions that promote, enhance, reinforce, and sustain T^2RM behaviors.

Applicability to Air Force Combat Team Training Initiatives

There has been increasing recognition in recent years of the need to train combat teams. This has led to initiatives that go beyond traditional crew-level CRM instruction and provide training environments for larger tactical teams. For example, DMT will provide networked simulation for tactically relevant multiship operations (Carroll & Andrews, 1997). Another example is Blue Flag, where an Air Operations Center (AOC) is "stood up" to exercise command and staff functions associated with deliberate and contingency planning. In this section, we consider the applicability of our methods and findings to planned Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA) research for these two applications.

DMT

The goal of DMT is to develop fully integrated, squadron-level, ground-based environments to train multiple aviators at multiple sites. The size of the team would range from individual and four-ship participation within a squadron up to full theater-level battles. Low-cost, high-fidelity simulators with full visual systems will immerse aircrews in a training arena, or "joint synthetic battlespace," with other air, ground, sea, and space forces to execute the air tasking order in a scenario developed and managed by the respective battle staffs (Carroll & Andrews, 1997). Several aspects of our T^2RM measurement model (Figure 1) appear to be germane to the Laboratory's DMT behavioral research program.

We view T^2RM performance as being multidimensional, and as a consequence, purposely developed a data collection scheme that attended to multiple facets of team coordination rather than focusing on one specific dimension. Our finding that four resource management subprocesses (SA, TE, FA, and TM) were reliably correlated with mission performance for MC-130P crews supports this view. We expect that performance in fighter aircraft would be similar. This multidimensional approach allowed us to be very specific about behaviors to monitor while maintaining a reasonable breadth of coverage. Although we expect our multidimensional view of team processes to generalize across team performance domains, we also expect the specific categories that constitute the most important behavioral dimensions to vary across aircraft types, missions, and even mission elements.

In a similar vein, we found that a combination of data sources was needed to delineate important T^2RM behaviors. Our rating data were amenable to statistical analyses that allowed us to identify those resource management areas that appeared to be reliable predictors of mission performance. While statistical analyses provided a good filter for identifying important aspects of team performance, the correlations were not particularly useful for specifying how training content or strategies might be improved. Recommendations for training improvement were

highly dependent on notes that accompanied our ratings describing training treatments (including feedback or the lack thereof) and specific behaviors associated with particularly strong or weak crew performance. A second critical source of understanding was interviews with instructors to interpret and partially validate the statistical findings.

Another important aspect of the present experimental approach, which we believe was a critical factor in finding statistically significant correlations between process and mission performance, was attending to team coordination processes, resulting mission performance, and eventual mission outcome (see Figure 1). The intervening mission performance module reflects the immediate consequences of the selected subprocesses during specific mission phases. The MC-130P crews were operating in an adaptive environment, both with respect to their ability to correct and modify behaviors in response to scenario events, and with respect to instructor modifications of the scenario to tailor difficulty to the capabilities of each crew. The intervening category of mission performance provides data that is essential if team coordination behaviors are to be linked with mission outcome measures such as airdrop accuracy or exposure to threats. This module helps control for external factors variable enemy actions, equipment malfunctions, weather, and luck that could otherwise obscure the effects of varying degrees of team coordination.

The hierarchical structure underlying our data set may also have merit in a DMT environment. There are two basic strategies that could be followed in measuring team performance. One is to identify and track large-scale, global variables that have broad appeal, but lack specificity for immediate implementation in CMT. The alternative is to identify and track particular context-specific behaviors that are more amenable to immediate training and reinforcement but which may have more limited generalization. Clearly, each approach has its strengths and weaknesses. Our data structure was designed to benefit from the best of both strategies by having an overall process rating and a total performance metric, but having each composed of more detailed data categories and elements that would enable a more detailed look at higher order relationships that achieved statistical significance. Once an overall T^2RM and team mission performance relationship was established, this structure allowed us to further specify which mission elements and which T^2RM subprocesses appeared to contribute to the effect.

The implications of the present research for the DMT program are at least twofold. First, a guiding assumption should be that DMT technology can support multiple, specific training goals. Substantial attention has been paid to using DMT for combat SA training. This is consistent with a portion of our findings. However, SA may be only one of many areas that can be effectively taught using DMT if accompanying training practices are properly designed and executed. Second, performance measurement for both trainee feedback and training effectiveness assessment needs to reflect the multidimensional nature of tactical team performance and the diverse needs of various users of the resulting data.

Blue Flag

A recent Blue Flag exercise provided an opportunity to overlay the five T^2RM subprocesses from the MC-130P study on a substantially different tactical team operation. Blue Flag involves standing up an AOC for three days to provide training on Air Tasking Order (ATO) generation. More specifically, the Night Guidance, Apportionment, and Targeting (NGAT) Cell was observed during Blue Flag 97-1. The NGAT is made up of an NGAT cell chief, a support group of about a half dozen Intel personnel, and nine specialized working groups (Navy aviation, strategic/attack assets, CAS, tanker support, and so forth) for a total of about 60 participants. As summarized below, the five T^2RM categories provided a useful template for organizing observations, and behaviors associated with these five categories accounted for much of the observable "learning curve" exhibited by Blue Flag participants.

SA - Approximately 90% of the participants had no AOC experience in either an exercise or actual combat operations. Although a basic process was briefed to the NGAT cell participants at the beginning of the exercise, the inexperienced participants expended a great deal of effort and time in the first night translating the conceptual process that was briefed into the reality of the AOC. Activities included determining what information was available pertaining to their function, where that information could be obtained, where their outputs needed to go, and how these products needed to be formatted. This appears to correspond to Endsley's (1995a) Level 1 SA. Processing input data to generate required products could correspond to her Level 2 SA. However, participants in this exercise were experienced warriors, and this level of processing appeared to fall quickly into place once the "big picture" of AOC operations was developed. Finally, over the course of the exercise, daily feedback concerning the previous day's products could be used by participants to generate a mental model of the consequences of their behavior to enable a better match between effort expended and likely benefits, corresponding to Endsley's Level 3 SA.

FA - An obvious change over the course of the exercise was how initially inexperienced working group leaders assigned work in their particular specialty group. A typical first night allocation of effort was for the group leader to allocate nothing because he had insufficient knowledge of the task or required products to assign elements to others. The obvious results were late products and frustrated team members. By the second night, allocation of tasks had vastly improved, with group leaders typically taking a coordination role while group members did the required labor-intensive information transformations and paperwork completion.

TE - The wing or squadron develops tactics *per se* upon receipt of the ATO. However, the NGAT participants who are responsible for developing elements of the ATO need to develop their parts in a way that a sound, tactical solution can be generated by the receiving organization. To assess this in Blue Flag exercises, selected operational units receive the resulting ATO and provide feedback that includes the tactical feasibility of their portions of the tasking.

TM - The NGAT process ends with a briefing to the Air Component Commander (in this case, a Lt General) at a prespecified time. The NGAT cell leader has a clear requirement to monitor progress in earlier steps of the process to accommodate the time needed to complete the

later steps within this finite time window. TM was given much more attention by the NGAT leader on Night 2 than it was on Night 1.

C3 - Communication among the working groups and between the working group and the NGAT leader forms the essence of the NGAT process. The NGAT chief for this exercise had developed checklists that specified coordination requirements and provided a place for initials to indicate that the required coordination had occurred.

Recommendations for Combat Mission Training

Data from the present study (particularly instructor and crew comments) imply that changes are needed in the CRM training that is conducted at the 58 TRSS. In this section, we discuss five areas from our research that we believe have implications for improving CRM training in both MQ and ART.

The **first area** pertains to generating a convincing position that the Formal School can better serve the SOF community through improved CRM or tactical team training. The present ART curriculum has evolved from a systems and EP training focus to the current tactical combat skills training emphasis. This evolution occurred based on requests made by crews during the Desert Storm period. In that time frame, crews were being regularly tasked to fly in operational missions over the Gulf, and they were reporting a high degree of proficiency in (basic) systems and EPs knowledge. However, they were also reporting a great need for focused tactics and threat training. These highly experienced crews recognized that if they were going to be required to rotate though a full week of ART, they should be receiving the training content they needed. These same crews also realized that the hallmark of the 58 TRSS, as a training system, was the ability to provide a tailored response to training needs. Thus, the ART curriculum was modified to accommodate this shift in stated needs, and embedded in this modified training practice was an expectation that an intense, combat mission scenario in the simulator was a good place to practice CRM skills and behaviors. However, the CRM scenario that we studied was developed without accompanying CRM training objectives.

In MQ, CRM is taught in academics to all MC-130P crewmembers using the generic AFSOC CRM workbook. Taking a "one-size-fits-all" approach to CRM training, AFSOC guidance does not address use of simulation for CRM training since some weapon systems do not have simulators for either MQ or ART--leaving it up to the Formal School to decide whether CRM training is a good use of scarce and expensive simulator resources. The AFSOC approach also does not address aircraft- or mission-specific requirements. Despite several attempts to demonstrate the effectiveness of generic CRM training, there is no data to our knowledge to support the value of this approach.

Several lines of evidence suggest that there is room for improvement in CRM training. First, our high correlations were possible only because we found a wide range of CRM behaviors and a wide range of mission performance levels across mission-qualified crews. Importantly, the differences between the extremes appear to be operationally meaningful. Second, instructor comments suggest that the lack of solid CRM skills complicates life on the flightline. We have

not yet delved into training records to build a better case, but that would be a logical next step. Third, as discussed in the first section, forward-leaning practitioners of CRM training who are held up as leaders in this business have discarded practices similar to ours in the areas of operational relevance and tailored training.

A critical activity is to identify specific problems that improved CRM training might impact either at the 550th SOS or in follow-on operational units. A focused problem analysis at the 550th SOS would be fairly straightforward. In the dynamic environment of the operational squadrons, we had proposed a mission information collection, analysis, and reporting system (MICARS) that would be an elegant solution to tracking drifting squadron needs (Spiker & Walls, 1995).

The **second area** pertains to establishing training objectives and associated behavioral criteria or requirements. These objectives should be platform-, mission-, and task-specific, and should include specifications for (a) which crewmembers are to perform which tasks, (b) the criterion level for task performance, and (c) the scope of the objective (e.g., does the objective apply to ART only, or does it cover MQ as well?). For example, both our process and performance data and SME comments reveal that mission teams demonstrate a high degree of variability in team coordination skill and mission performance across the observed mission phases (i.e., MP, LL, AR, AD, and I/E). This data also indicate that a crew's level of successful mission execution performance is a function of the scripted mission scenario's level of challenge. Additionally, crew performance tends to improve when they are permitted to operate in a low-threat, minimum-difficulty mission environment. Given a marginally higher threat environment, however, crew coordination and mission operations performance (e.g., chaff and flare expendables discipline) shows a definite downward trend. If criterion-based objective standards for performance existed, we could more reasonably state, in simple terms, the underlying reasons for a crew's poor performance.

The level of mission challenge is a direct function of how simulator instructors manipulate the scripted and unscripted threat environment. We have also observed a wide range of variability in scenario manipulation that is provided by instructor crews, and our data suggest evidence of disparate levels of simulator systems and/or Integrated Electric Combat Simulation System knowledge. Changing threat system variables and/or scenario manipulation has been reported as a difficult, time-consuming process, and oftentimes the cause of simulator malfunction. Thus, instructors typically avoid scenario script manipulation resulting in artificially low levels of task difficulty and corresponding unmotivated student response. In this context, the Laboratory is working with the 58 TRSS on a project to improve the user interface of the IOS to lower the difficulty of manipulating selected scenario properties and relieve some of this problem. Another facet of the problem is the lack of standardized training objectives and methods that promote high-performance learning to desired criterion levels.

The **third area** is the need for CRM training methods to satisfy training objectives. We have noted that crews perceive a lack of relevance to their CRM training. On the first day of ART, a short overview of the "CRM Pyramid" (Wilson, 1995) is presented. Following this, a dialogue period is provided for volunteers to identify any related problems, or "war stories," that

may have been recently experienced. Specifically, ART crewmembers are solicited to report, on a nonattribution basis, any personal or other knowledge of recent violations of any level in the CRM pyramid of principles. This may include certain crewmember actions, systemic issues, or even organizational problems. While the intent is admirable, the resultant exchange is usually less than desired. Since crews generally arrive from the same organizations, it should not be surprising that students are reluctant to (publicly) divulge information that may incriminate others with whom they have to regularly fly, or to whom they are required to report.

Following this academic training period, students are not required to perform any CRM-related skills and behaviors until the CMT scenario provided on the last day of ART (and then with unknown performance objectives and criteria, as previously discussed). Our observational data support changing the overall CRM training method to achieve specific team coordination training objectives, and provide an emphasis on CRM skill performance to meet certain criterion levels. We envision a revamped CRM curriculum that includes, for example: academic training on the emphasis of complete use of all knowledge and personnel resources (the CSO, especially); a re-thinking of traditional crew position roles and/or responsibilities; a tailoring of the training matter to include weapons-specific and tactically relevant, topical matter; and an increased coordination of high-intensity threat and mission tactics. Finally, a modular approach to simulator utilization, and a flexible approach to CMT scenario construction, should be employed.

The **fourth area** concerns feedback both to student crews concerning CRM performance and to the training organization concerning the effectiveness of the training itself. With respect to student feedback, we observed that, while there was a wide range in how well the crews performed in our study, there was unfortunately little difference in how the crews were debriefed by the instructors. Crews were given very little explicit feedback concerning deficiencies in their crew coordination processes, either during mission planning or while they were performing the simulator mission. A valuable opportunity to correct deficient behaviors and reinforce effective behaviors is therefore lost. Additionally, instructors are demonstrating a certain acceptance of traditional student critique methods that are focused only on aspects of procedural performance.

The problem has several facets. The first is that there is no consensus that CRM is, in reality, a training objective of the scenario. In fact, there is some feeling among the contractor instructors that the USAF does <u>not</u> actively view CRM as an appropriate feedback topic area because it falls into the area of technique. Another problem is that no method exists for instructors to provide students with comprehensive individual or crew assessments of mission or crew coordination performance. The current method of critique and feedback reduces the tactical scenario to an individual, part-task training level, and does not address the individual or crew aspects of team coordination and mission performance. Informal discussions with several CRM trainers revealed that lack of meaningful feedback precludes, for the most part, any beneficial impact of the scenario on future student performance.

Students need to be informed when their coordination performance is poor or substandard, otherwise training cannot hope to change inadequate or inappropriate behavior. We acknowledge that instructors are capable of providing this feedback, but they are not afforded either the direction (or even permission) or the <u>tools</u> to provide a focused, or memorable structure in their

debrief. We would advise development of an instructor's debrief tool (probably in checklist format) that would enable instructors to use the debrief period as an opportunity to comment on tactical proficiency, reinforce good CRM behaviors, and critique on poor CRM behaviors.

A **fifth area** to consider is MP training. Our data demonstrate that comprehensive MP by the crew is an extremely important factor to ensure mission operations success, but this activity is not being supported at the ART level. Specifically, the degree of importance placed on MP correlates to direct and immediate impact on mission execution performance. There is a tendency, however, to reduce the MP period to a somewhat lesser role in the overall training process. In this vein, MP is being viewed as a separate training period from the actual simulator training period.

We recommend better incorporation of advanced planning materials and semiautomated systems (e.g., SOFPARS) into the MP process. We advocate development of methods for students to structure their own "team" coordination activities to promote effective planning activities. Students need to be informed of prescriptive approaches to promote their effective mission team coordination skill, rather than being allowed to operate under a presumption that good performance will "just happen" as they conduct their normal MP activities. We would include an academic review session in ART that covers effective MP procedures and techniques, as well as methods for incorporation of advanced planning methods and materials. Finally, we would extend the T^2RM concepts into the MP phase, where there is ample time and opportunity for instructors to identify when and where problem behaviors are being exhibited.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

58 TRSS	58th Training Support Squadron
ABCCC	Airborne Command, Control, and Communications
AC	Aircraft Commander
ACT	Aircrew Coordination Training
AD	Airdrop
AFSOC	Air Force Special Operations Command
AFSOCR	Air Force Special Operations Command Regulation
AFRL/HEA	Air Force Research Laboratory/ Warfighter Training Research Division
AO	Area of Operation
AOC	Air Operations Center
AR	Air Refueling
ART	Annual Refresher Training
ATC	Air Traffic Control
ATO	Air Tasking Order
BARS	Behaviorally Anchored Rating Scale
BQ	Basic Quality
C3	Command, Control, and Communications
C&C	Command and Control
CARP	Computer Air Release Point
CAS	Close Air Support
CEOI	Communications Execution Operating Instruction
CMAQ	Crewmember Management Attitudes Questionnaire
CBS	Crewmember Background Survey
CMT	Combat Mission Training
COA	Course of Action
CP	Copilot
CRM	Crew Resource Management
CSO	Communication System Operator
DIS	Distributed Interactive Simulation
DMT	Distributed Mission Training
DZ	Drop Zone
E&E	Escape and Evasion
EPs	Emergency Procedures
EW	Electronic Warfare
FA	Function Allocation
FE	Flight Engineer
FRAG	Fragmentary Order

GTM	Ground Track Map
HTI	Hughes Training, Inc.
IDS	Infared Detection System
I/E	Infil/Exfil
IMOMS	Integrated Mini on Mini System
INS	Inertial Navigation System
INTEL	Intelligence
IOS	Instructor Operator Station
IP	Instructor Pilot
IRI	Instructor Rating Instrument
KAFB	Kirtland Air Force Base
LL	Low-Level
LM	Loadmaster
LN	Left Navigator
LOS	Line Operational Simulation
LZ	Landing Zone
MEDEVAC	Medical Evacuation
MICARS	Mission Information Collection, Analysis, and Reporting System
MM-MM	Multimeasure Multimethod
MOST	Mission-Oriented Simulator Training
MP	Mission Preparation
MQ	Mission Qualification
MR	Mission Rehearsal
MRA	Multiple Regression Analysis
MTSS	Mission Training Support System
NGAT	Night Guidance, Apportionment, and Targeting
NVG	Night Vision Goggles
OC	Observer/Controller
PF	Pilot Flying
PJ	Pararescue Jumper
P/O	Participant/Observer
R&D	Research and Development
RN	Right Navigator

SA	Situation Awareness
SAFE	Selected Area for Evasion
SCA	Self-Contained Approach
SF	Special Forces
SITREP	Situation Report
SME	Subject-Matter Expert
SOF	Special Operations Forces
SOFI	Special Operations Forces Improvements
SOFPARS	Special Operations Forces Preparation and Rehearsal System
SOS	Special Operations Squadron
SNS	Satellite Navigation System
STAN/EVAL	Standardization/Evaluation
TARGETs	Targeted Acceptable Responses to Generated Events and Tasks
T^2RM	Tactical Team Resource Management
TE	Tactics Employment
TM	Time Management
TMAQ1	pre-Team Mission Attitudes Questionnaire
TMAQ2	post-Team Mission Attitudes Questionnaire
TOLD	Takeoff and Landing Data
TOT	Time on Target
T-MOT	Team-Mission Observation Tool
T-MPT	Team-Mission Performance Tool
T-MRAT	Team-Mission Readiness Assessment Tool
USAF	United States Air Force
WST	Weapon Systems Trainer

APPENDIX A

Descriptive Profiles of the 11 MC-130P Crews

CREW #2

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	34	7	25	43
MC-130P Flying Hrs	6	1675	1306	0	3500
Total Flying Hrs	6	2766	1515	1500	5700
CRM Hrs	6	44	42	15	125
Hrs Experience in AO	5	101	223	0	500

POSITIONS		RANKS		SQUADRON	
AC	1	Maj	1	Other	3
CP	1	Capt	3	"B" SOS	3
NAV	2	MSgt	1		
FE	1	Amn	1		
CSO	1				

CREW #3

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	33	3	28	36
MC-130P Flying Hrs	6	1183	964	200	2600
Total Flying Hrs	6	2967	1521	1500	5800
CRM Hrs	5	34	37	11	100
Hrs Experience in AO	6	70	71	12	200

POSITIONS		RANKS		SQUADRON	
AC	1	Maj	1	"D" SOS	6
CP	1	Capt	3		
NAV	2	MSgt	1		
FE	1	SSgt	1		
CSO	1				

CREW #4

	N	Mean	Std Deviation	Minimum	Maximum
Age	7	34	5	27	41
MC-130P Flying Hrs	7	1479	1179	100	3000
Total Flying Hrs	7	3200	1264	1500	4700
CRM Hrs	7	32	18	10	60
Hrs Experience in AO	7	697	1149	0	2950

POSITIONS		RANKS		SQUADRON	
AC	1	Maj	1	Other	1
CP	1	Capt	3	"C" SOS	6
NAV	2	TSgt	1		
FE	1	SSgt	2		
CSO	2				

CREW #5

	N	Mean	Std Deviation	Minimum	Maximum
Age	7	41	5	35	48
MC-130P Flying Hrs	7	921	1381	150	4000
Total Flying Hrs	7	3843	1621	1700	6500
CRM Hrs	7	18	13	0	40
Hrs Experience in AO	7	395	560	0	1500

POSITIONS		RANKS		SQUADRON	
AC	1	Ltc	1	Other	1
CP	1	Maj	1	"A" SOS	6
NAV	2	Capt	2		
FE	1	MSgt	1		
CSO	2	TSgt	2		

CREW #6

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	34	3	30	40
MC-130P Flying Hrs	6	863	1083	125	3000
Total Flying Hrs	6	2739	1103	875	3800
CRM Hrs	6	33	18	12	65
Hrs Experience in AO	6	558	1199	7	3000

POSITIONS		RANKS		SQUADRON	
AC	1	Maj	1	"D" SOS	6
CP	1	Capt	3		
NAV	2	MSgt	1		
FE	1	Amn	1		
CSO	1				

CREW #7

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	33	4	28	39
MC-130P Flying Hrs	6	1162	439	500	1600
Total Flying Hrs	6	2262	1036	971	3500
CRM Hrs	6	92	82	8	200
Hrs Experience in AO	5	336	707	0	1600

POSITIONS		RANKS		SQUADRON	
AC	1				
CP	1	Capt	4		
NAV	2	TSgt	1	"B" SOS	6
FE	1	SSgt	1		
CSO	1				

CREW #9

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	35	6	29	45
MC-130P Flying Hrs	6	1375	1257	200	2900
Total Flying Hrs	6	2767	1473	500	4800
CRM Hrs	6	20	10	4	30
Hrs Experience in AO	6	50	99	0	250

POSITIONS		RANKS		SQUADRON	
AC	1	Ltc	1		
CP	1	Capt	3	Other	1
NAV	2	TSgt	1	"C" SOS	5
FE	1	SSgt	1		
CSO	1				

CREW #10

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	32	3	30	38
MC-130P Flying Hrs	6	1392	548	700	1950
Total Flying Hrs	6	3225	1425	2300	6100
CRM Hrs	6	52	18	26	75
Hrs Experience in AO	6	534	1003	0	2500

POSITIONS		RANKS		SQUADRON	
AC	1	Maj	1		
CP	1	Capt	3		
NAV	2	SSgt	2	"B" SOS	6
FE	1				
CSO	1				

CREW #11

	N	Mean	Std Deviation	Minimum	Maximum
Age	5	36	7	31	47
MC-130P Flying Hrs	5	740	623	200	1800
Total Flying Hrs	5	3180	2216	1600	7000
CRM Hrs	5	23	16	8	50
Hrs Experience in AO	5	85	176	0	400

POSITIONS		RANKS		SQUADRON	
AC	1				
CP	1	Capt	4	"A" SOS	4
NAV	2	MSgt	1	"B" SOS	1
FE	1				
CSO	0				

CREW #12

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	31	3	27	36
MC-130P Flying Hrs	6	975	593	400	2000
Total Flying Hrs	6	2913	2103	1275	7000
CRM Hrs	5	16	14	4	36
Hrs Experience in AO	6	130	111	0	300

POSITIONS		RANKS		SQUADRON	
AC	1				
CP	1	Capt	4	"C" SOS	1
NAV	2	MSgt	1	"D" SOS	5
FE	1	SSgt	1		
CSO	1				

CREW #13

	N	Mean	Std Deviation	Minimum	Maximum
Age	6	35	3	31	40
MC-130P Flying Hrs	6	2325	2667	400	7550
Total Flying Hrs	6	3625	1988	2300	7550
CRM Hrs	5	38	19	20	64
Hrs Experience in AO	5	72	54	10	150

POSITIONS		RANKS		SQUADRON	
AC	1	Ltc	1		
CP	1	Capt	3		
NAV	2	TSgt	1	"D" SOS	6
FE	1	SSgt	1		
CSO	1				

APPENDIX B

Examples of TE, FA, SA, and C3 Subprocess Assessments from the T-MOT.

Tactics Employment (TE): Includes all analytic activities necessary to avoid or minimize threat detection, or exposure, and to successfully coordinate complex mission events and multiple mission objectives.

2.0 There are (typically) three tactical options to use in order to go undetected: Altitude, Airspeed, and Terrain.

a. Was a particular mix of tactics options considered? .... YES / NO
(Explain) ______

b. Did the crew change the tactics options as a function of difficulty in each mission phase? .... YES/NO
(Explain) ______

c. Was one option (e.g., speed) preferred over the others? .... YES/NO
(Explain) ______

d. Did any crewmember periodically review or verify the status of the threat planning strategy? ..... YES/NO
(Explain) ______

Function Allocation (FA): Includes the division of crew responsibilities so that workload is distributed among the crew, avoiding redundant tasking, task overload, and crewmember disinterest or noninvolvement. Tasks should be allocated in such a manner so that crewmembers are able to share information and coordinate responsibilities.

3.0 Workload and/or task distribution should be clearly communicated and acknowledged by crewmembers.

a. Was the mission workload distribution clearly communicated and acknowledged? .... YES/NO
(Explain) ______

b. Were secondary tasks prioritized so as to allow sufficient resources for primary tasks?........... YES/NO
(Explain) ______

c. Did nonoperational factors (such as social interaction) interfere with any crewmember is abilities while performing necessary tasks?... YES/NO
(Explain______

Situation Awareness (SA): Entails maintaining an accurate mental picture of mission events and objectives as they unfold over time and space. Emphasis and analysis are placed on the three levels of SA (perception, integration, and generation: Endsley, 1995b) and their impact on team coordination.

4.0 At least one crewmember's overall SA should be high, and an assessment of mission difficulty should be made based on (for example): marginal weather, threat saturation is high, large no. of mission events, etc.

a. Did any individual crewmember indicate an overall assessment of mission difficulty? .... YES/NO
(Explain) ______

b. Did crewmember(s) prepare for unexpected or contingency situations? .... YES/NO
(Explain) ______

Command, Control, and Communications (C3): Encompasses those activities required to involve external parties in the mission, and to maintain communications with these external team members; communication within the crew; and controlling the sequence of mission events according to the mission execution plan.

5.0 Crew's willingness to challenge the system.

a. Do crewmembers request specific resources they need? .... YES/NO
   (Explain) ____________________

b. Do crewmembers question/challenge assumptions (e.g., within frag, threat SITREP, etc.)? ...... YES/NO
   (Explain) ____________________

c. Do crewmembers ferret out needed materials and information from all sources? .... YES/NO
   (Explain) ____________________